A Malariologist In Many Lands

Marshall A. Barber

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by

Marshall A. Barber

with a foreword by
Paul F. Russell

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PREFACE

This book aims to give, in a simple form, some account of my anti-malaria work in various parts of the world. The more technical aspects of this work have already been discussed, some of them in scientific journals and some in lectures given to the students of the Army Medical School at Washington; I have included here only such details as may help to clarify the main topic—malaria, its prevalence and prevention, in various parts of the world. I have given considerable space to the natural history of the mosquito vectors, a knowledge of which, I trust, will aid in understanding the methods of preventing the disease.

Malaria is the cause of a large proportion of the sickness and death in the world. I have long believed that popular education, especially that which has to do with its method of transmission, will help much to get rid of the malady. It is surprising how the old misconceptions persist—for example, that people must guard against night air, rotting vegetation, or even green fruits if they are to remain healthy in localities where the disease occurs. I hope that this simple narrative will promote unlearning as well as learning in this subject.

I have arranged the chapters in a roughly chronological order.

I am under obligations to the Public Health Service for permission to quote from its reports, to The Rockefeller Foundation for the use of illustrative material, and to Mr. Mehmed Aziz for certain photographs.

Kansas City, Missouri, M.A.B.
February 15, 1946

FOREWORD

Malaria is a disease of paramount importance today. Directly or indirectly it affects most of the world's inhabitants. In the tropics and many subtropical and temperate countries it is a crippling blight which debilitates or kills hundreds of thousands. In nonmalarious areas the effect of this disease on agricultural development elsewhere is reflected in higher prices for rubber, sugar, vegetable oils, and similar products. Vast territories remain undeveloped chiefly because of malaria. No one knows the total incidence, but estimates of 300,000,000 cases annually with 3,000,000 deaths directly due to this disease are probably conservative. World War II, like all great wars, has markedly increased and intensified the problem. Authoritative books on malaria, therefore, have an unusual claim on our attention. Here is one written by a malariologist of world-wide renown.

Doctor Barber has been chasing malaria plasmodia and their anopheles vectors for half a century, prying into their secret habits and paving the way for their destruction. He has outwalked more mosquito-collectors in more countries than any other malariologist of record. In the United States, Central and South America, the West Indies, Equatorial Africa, Egypt, Turkey, Cyprus, Greek Macedonia, Russia, India, Malaya, the Philippines, and elsewhere, Doctor Barber has contributed materially to the science of malariology. Throughout his career, whether in temperate or equatorial surroundings, two characteristics—energy and originality—have been outstanding. His mind has been as active as his feet and has led the way to new procedures of great value.

Take, for example, the destruction of the larvae of anopheles with Paris green. In all the years man has been trying to control mosquitoes he has developed, speaking practically and in general terms, only three effective larvicides. These are oil, Paris green, and recently DDT. To Doctor Barber belongs the credit for discovering the second. With a young assistant, T. B. Hayne, in 1921

he confirmed Roubaud's report that powdered trioxymethylene will kill larvae. Then, characteristically, Barber set out to find a cheaper and more effective powder and before long added Paris green to the armamentarium for malaria control. Since then hundreds of thousands of tons of this substance have been used throughout the world to kill anopheline larvae, with incalculable benefit to millions of people.

In another demonstration of originality, Doctor Barber in 1935, with Justus B. Rice, improved a cumbersome and laborious precipitin test so that it could be used rapidly and cheaply to determine the source of blood meals of thousands of mosquitoes. This basic work made it feasible to measure on a large scale the amount of contact between anopheles and man and thus to focus attention on the one or two species chiefly responsible for spreading malaria in any given region.

Many other illustrations could be given. Whether obtaining relaxed abdominal walls for better spleen palpation by having Moslem children recite the Koran, or manipulating and dissecting single microscopic organisms long before the modern micromanipulators had been invented, or being first to prove that Paris green will effectively destroy the larvae of anopheles, Doctor Barber has displayed notable originality throughout his long and distinguished career.

The aim of this book, as stated, has been to give a simple account of the author's experiences in his malaria work in various parts of the world in order to promote the "unlearning" of some misconceptions and the learning of simple truths about this important disease. It seems to me that Doctor Barber has fully accomplished his purpose in a most interesting way.

PAUL F. RUSSELL, COLONEL, MEDICAL CORPS, AUS
(on leave from The Rockefeller Foundation)

Washington, D.C.,
25 February 1946

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A MALARIOLOGIST IN MANY LANDS

CHAPTER ONE: THE UNITED STATES

My first recollection of malaria, or alleged malaria, is of a time in southeastern Kansas when my mother gave me quinine for "dumb ague." That was the period when, capsules being unknown, one swallowed the drug mixed with water in a tablespoon: I remember well that it was not in a teaspoon. In Missouri, I am told, the people knew how to envelope quinine in wet slippery-elm bark; then all went down smoothly and, I am sure, less bitterly. We had plenty of slippery-elm bark in our woods—we children were fond of chewing it—but we had never heard of the Missouri method of using it to ease down quinine. I do not know exactly what the "dumb ague" was, but we undoubtedly had real malaria in Kansas at that time.

My first visual acquaintance with malaria parasites came about 1895, when I was a junior instructor in the University of Kansas. A patient with infected blood was brought to my attention by Dr. S. W. Williston, my old friend and colleague. As all malaria-interested people know, Dr. Williston, a most intelligently versatile man, wrote an authoritative book on mosquitoes before he went into paleontology.

At that time we knew little of the modern methods of preparation of malarial blood for microscopic examination: how one spreads the blood on a slip of glass, dries it, then "fixes" it with ethyl alcohol, which surely kills the parasites. (To the beginner those dried parasites may already seem dead enough!) After fixation one stains the preparation in aniline colors, red and purple; then it is ready for examination under the microscope. This device prepares the parasites very well for study, but, like the epitaph on a tombstone, although very useful for identification, may be but slightly informative about the characteristics of the subject.

The parasites from Dr. Williston's patient were unstained and still alive, and I saw them moving within the red corpuscles of the patient just as they do when he is feverish. At one time the de-

tection of malaria parasites in the blood was made with fresh, unstained blood; and such examination is still an excellent procedure for the beginner, for it teaches him what the living parasites look like.

I renewed my experience with malaria in the United States during World War I, when we did minor surveys at Camp Jackson, South Carolina, where I was stationed. Our unit had no formal connection with malaria prevention, but we searched around the camp to see what anopheline larvae we could find, and examined the blood of a large number of soldiers for malaria parasites. We found little evidence of serious malaria transmission in either quarter; I think we found but one positive among a hundred soldiers. My more extensive malaria work in the United States began in 1920, when I joined the United States Public Health Service.

Malaria was once vastly more abundant in this country than it is now. How much there was among the aborigines at the time of the arrival of Columbus we do not know. Dr. Henry Carter, of yellow fever fame, who made an extensive study of the prevalence of malaria and yellow fever at the time of the early explorations, was of the opinion that neither disease was present in the Americas at the time of their discovery by Columbus. Columbus mentions "the abundance of fine streams of water, which are not pestilent, like the rivers of Guinea, for, praised be our Lord, there has not as yet been one among all my crews brought on his bed by sickness, or even afflicted with so much as a headache, excepting an old man who was troubled two days with the stone. . . ."[1] The people of the West Indies, of whom Columbus writes, were then numerous and in relatively close contact with the Spaniards; and it is said that Columbus had formerly voyaged as far as Guinea in Africa and knew something of "pestilent" rivers.

Other authors believe that malaria was known to the aborigines of South America, arguing that since the Peruvians knew of the remedy for malaria, the cinchona bark from which quinine is extracted, they must have known of the disease itself.

[1] *Journal of First Voyage to America by Christopher Columbus*, New York, 1924, p. 91.

However, what we know of malaria during the earlier colonization of the Americas is consistent with the theory that the colonizers brought the disease with them from Europe. Practically all of the early explorers came from countries in which malaria was present. We know it once existed as far north as Denmark, and possibly it was endemic still farther north. It may be that even Leif Ericson and his Scandinavian crew carried the disease in their veins to North America. The parasites of malaria, unlike the virus of yellow fever, may remain in the human body for years, and might have persisted in those aborigines who entered the Western Hemisphere in prehistoric times, even in those who came from homelands situated north of the present range of malaria. And it is very probable that when malaria arrived here, it found anopheles mosquitoes already on the ground—the explorers did not have to carry them in.

Whatever its origin, it soon became apparent in the Americas. According to one account, Columbus himself, in later voyages to America, suffered from what may have been malaria, and we have abundant evidence of the prevalence of fevers, probably malarial, among the English colonists of North America. England in early times had plenty of "ague" and quite possibly the settlers of Jamestown brought some of it with them, even if they did not find it among the Indians of the country. One author of somewhat later times doubted the possibility of settling a country so saturated with this malady. Long after the Revolution, it occurred in many states, and during the Civil War it accounted for much illness among the troops and was brought home by returning soldiers. These, it is stated, lighted up many foci of the disease in their home neighborhoods. After the Civil War it remained prevalent even in the northern part of the continent. Osler states, "Parts of the Province of Ontario were hotbeds of the disease, which within my memory has disappeared from the districts about the western end of Lake Ontario and the northern shores of Lake Erie."

We had the disease in Kansas during my childhood, although it was much less prevalent there than in many states. Newcomers

to the region often came down with fever, and there was occasionally a fatal form known as "congestive chills," probably a cerebral phase of the disease. The Kansas of those days did not look like a malarious country and probably most of it was not; but the early settlers, like the anopheles, preferred to live along the streams where the fertile, better-watered soil grew both corn and mosquitoes—the vast prairies between the streams did not then grow much of either. It was in those creek or river bottoms that most of the malaria occurred.

Malaria was prevalent in northern Indiana in the 1860's. My parents have told me of autumns when there were hardly enough well people to take care of the sick. We have evidence of its prevalence in other northern and north-central states. Dr. V. C. Vaughn wrote me that in the early eighties death rates from malaria in Michigan ran about twenty per 100,000. Mr. J. A. LePrince states that malaria was not uncommon on Manhattan Island, where he lived at about the same time. He himself suffered from a three weeks' attack and his brother had it every autumn. Dr. Henry Carter wrote me regarding malaria in Illinois:

> In the country just north of Cairo, Illinois, in 1879, malaria was excessively prevalent. Few were living in that country save Negroes. They were only farming it. The food in this country—I have eaten at their houses—was coarse and with little variety, but rather more than abundant. The houses of the whites were good to fairly good. Few screens. I visited it again in the fall of 1887. Malaria still prevailed here but not more than twenty-five percent of what I had seen before. The Negroes, who had partly cleared and ditched the land, had been replaced by white farmers. In 1910 I visited Cairo a third time, and was told, although I did not go into the "bottoms," that while there was malaria there, there was no great deal. Very few Negroes, and the land was mainly drained. It was not a stock country, corn and hay being the main crops—the first mainly.

I include here the same author's graphic account of malaria in Virginia at a somewhat earlier time:

> There was a great increase of malaria after the Civil War in my section of Virginia—just above tidewater. The country had never been free from malaria; but on our plantation, at least, it had not been of sanitary importance for a number of years. After the war several of the family had it

—I and two little sisters—and it was fairly general, though not severe all over the neighborhood.

Living conditions were hard. From the time Sheridan went through, in April, 1865, we had no meat of any kind—save a few birds and two rabbits that we boys killed with stones (firearms had been taken away)—until November 18, when we killed a wild hog (a descendant of tame ones) in a trap. We had a little flour, and our family lived practically on partially spoiled corn (the "nubbin pile"—all the rest had been taken), potatoes and wild salad plants, especially water cress. In land our people were rich (there were some 1600 acres in that plantation), and I judge our neighbors fed no better than we. . . . Malaria gradually disappeared here as the country resumed its former status, retreating toward the east.

Dr. A. E. Hertzler has written me of his cases of malaria, about 150 laboratory-diagnosed, in Kansas during the horse-and-buggy days. These cases were in the open prairie country of central Kansas where once the buffalo abounded.

A physician of southeastern Missouri has told me of the vast amount of the disease present during early times in that region, where it existed, although to a lesser extent, up to very recent years. He describes how a doctor on his early morning rounds would see a light in nearly every house—everywhere people were up attending their sick.

It is true that sometimes sickness due to some other cause was attributed to malaria, which was certainly blamed for many typhoid deaths. Not until 1880, when Laveran discovered the parasite of malaria in the human blood, was the diagnosis of malaria put on a thoroughly scientific basis. But shortly after the discovery of the parasite, the disease was diagnosed microscopically in many localities, particularly in the Massachusetts General Hospital, in Johns Hopkins Hospital, and in many other parts of the country; as, for example, by Dr. Hertzler in Kansas. So we know by laboratory diagnosis that malaria was once very prevalent.

But the clinical diagnosis is often unmistakable. In no other disease does one have such a characteristic alternation of sick and well days. Nor does any other disease yield so generally to treatment by quinine: the success of the specific remedy confirms the diagnosis.

A graphic account is given of the diagnosis, both medical and nonmedical, by Joseph G. Cannon, formerly Speaker of the House of Representatives, whose father was a country physician in Indiana during the early times:

> We had standard diseases and standard remedies on the Wabash. We had ague as a regular disease, and it was not difficult to diagnose. You could feel it and you could see it with the naked eye. Other people could also feel it when the patient had a chill, for he shook the house. Our standard remedies for ague were calomel, castor oil, and quinine, and they were not measured out in the apothecaries' scales. Ten grains of calomel was the dose for a congestive chill, followed with a big dose of castor oil and then all the quinine that could be poured into the victim. We did not have capsules to protect the quinine until it got into the stomach. It was in powder and had to be swallowed raw or diluted in water, and in either case it was medicine, patently so to the patient in trying to swallow it.

I have been a victim of malaria myself and had no difficulty in recognizing a threatening attack by the "feeling in the bones," and later I was not surprised to find the parasites in my blood. One man told me that he could always tell when malaria was coming on because "water no longer tastes right." Perhaps this symptom has led many people to fortify the water strongly with whiskey and quinine. Like the rattlesnake, malaria was generally decent enough to give a preliminary warning of its approach. Then well-advised people used to reach to the mantel for a dose of quinine in the hope of warding off the attack before it could get a strong hold. If it came on anyhow, they had no trouble in diagnosing most of the cases without consulting a microscope. Microscopes would have done little good in the pioneer times; none of the doctors had them or would have known what to look for if they had had them.

There is still a considerable amount of malaria in this country, especially along the river valleys in the southern states. But it has become almost extinct in the North and has become far less common in the South.

I do not include here the occasional cases—in large cities usually—which come from the use of a syringe among narcotic addicts. Such an addict happens to have parasites in his veins,

perhaps carried from a malarious homeland in southern Europe. When the crowd passes the dope-laden syringe from person to person, the needle of that instrument carries the parasites with it, and a small outbreak of malaria may follow.

That malaria declined more slowly in the southern states is not surprising. In the North the season when the temperature is warm enough for the maturation of the malaria parasite in the mosquito is much shorter, and the patient has a longer winter to aid him in recovery from the disease. Then, too, the North has far fewer Negroes living on farms, rural regions being notably the places where malaria transmission is most prevalent. Negroes have long served as reservoirs of malaria parasites. Although perhaps suffering less from an attack of the disease than do white persons, they are probably quite as easily infected, certainly by the estivo-autumnal form of parasite. As a rule, Negroes are less protected from mosquito bites; and since they are more often neglectful of treatment, they are likely to harbor the parasite for long periods of time.

Of course any neglected people will serve as a reservoir of infectious disease. But with respect to malaria, Negroes are a particularly efficient reservoir or at least have been in the past. Equatorial Africa is stocked with species and strains of malaria parasite in great variety and abundance, and thousands of Negroes must have been loaded with them when the ships of the "Middle Passage" brought the Negro slaves to the Americas. There they remained an abundant source of infection, a menace to their former masters many years after slavery was abolished. Thus the Dark Continent avenged itself for the theft of its children.

It becomes of interest to inquire the reason for the great decrease in malaria in this country and for a similar decrease in northern and central Europe. It is true that anti-malaria activities have greatly increased in America and Europe, and undoubtedly they may account for some of the decrease; but much of this decline took place before we knew how malaria is transmitted—a discovery made very late in the last century—so that a great proportion of the falling off in malaria occurred independently of any

conscious effort on our part. And the decline is almost universal in this country, and has taken place in many localities where no conscious antimalarial work has been undertaken. The character of the decrease leads us to look for some widely distributed cause.

The use of screens increased greatly during the 1870's and 1880's. As a child I was impressed by the quantities of flies and mosquitoes which swarmed in dwellings. On autumn nights branches from the orchard were hung to the ceilings, where myriads of flies would collect and become stupefied by the cold. In the morning, if I got up early enough, I might see these insect-covered branches taken out and burned.

Later in the 1870's, we began to use cloth screens for doors and windows and finally wire screens, which we often took down in the autumn and stored during the winter. While many mosquitoes got through the imperfect barriers of those times, they afforded us some protection, and undoubtedly screening had much to do with the decrease of malaria in the United States; but we must remember that in parts of Europe where screens were used but little or not at all, malaria also decreased during the same period. Bed nets were more commonly used there than screens.

It must be emphasized that the success of screens in malaria prevention depends on their proper use. I worked in one locality in New Mexico where the people screened their houses fairly well, but mainly for the purpose of keeping out flies in the daytime; they may not have heard that mosquitoes carry malaria, and if they had they hardly believed in the "theory." At night the screen doors might not be properly closed, or in hot weather people might often sleep out of doors. Malaria rapidly increased in this locality in spite of screens. With screens should go a proper education in regard to the manner in which malaria is transmitted.

Many houses, especially in newly settled localities, are hard to screen. "What is the use?" people say. "The roof is full of holes where mosquitoes can get in." Often that remark is made to excuse an unwillingness to take a little trouble, and by people who

are only half convinced that mosquitoes really have anything to do with the spread of disease. But if they were fully persuaded that the entrance of mosquitoes means more than mere annoyance, they would be willing to take any amount of pains to avoid it. They would stuff crannies with cotton, and rig up some kind of netting rather than spend an autumn with attacks of chills and fever. And the early settlers had the less labor because they had such small cabins to screen. I have seen cabins made literally of mud and sticks—hardly more elaborate in construction than a bird's nest—well provided with a door screen, which kept out the flies in the daytime but which may have been propped open at night—the very time when malaria-carrying mosquitoes are most active.

Without doubt, the use of quinine contributed much to the decrease of malaria in this country. Quinine was once relatively expensive, and its use increased when the price fell; the cheapening was due, it is alleged, to the removal of an excessive tariff on the drug. Dr. Henry Carter, writing on malaria in North Carolina, ascribes much of the decrease of malaria there to the lowered price of quinine. At the time when the drug was most needed, it cost $4 to $4.50 an ounce and was used but sparingly by poor people, being rarely taken by them except on a doctor's prescription. In 1913, it cost only twenty-five to twenty-eight cents an ounce and was then administered in large doses by the farmers themselves, and the treatment was longer continued.

Possibly it came to be too freely used in this country and too often without medical direction. Quinine is considered a rather safe drug, but is not tolerated by some persons and there is a limit to the size of a safe dose for anybody. It has been used in some countries as a means of suicide—rather unsuccessfully, but such use suggests its danger when taken in overdose. As a remedy, it has not the power which some drugs possess of killing all forms of the parasite, the mature male and female forms particularly. However, quinine cures the illness, or, at all events, shortens the period of time during which malaria parasites flourish; and thus it greatly reduces the chances of infecting mosquitoes.

Along with the increase in the prosperity of the country came more doctors and a greater use of medical advice, contributing greatly to a more logical treatment of the disease. Trained doctors and remedies are conspicuously lacking in most countries with a high incidence of malaria, such as we frequently find in parts of Asia or Africa. The people often cannot afford such luxuries and sometimes cannot be made to trust them; but it is remarkable how soon they come to employ them when they can afford to do so and have seen their efficiency.

The diminution of anopheles through agricultural drainage probably also had much to do with the decrease of malaria in this country. The importance of this factor varied greatly in different localities. Where large areas were drained, as was the case in my native Indiana, the amount of mosquito breeding was greatly diminished. As a youth in the early 1880's, I visited my old home in that state and was much impressed by the manufacture of tile and its wide use in drying up the land. I may have been more impressed at seeing the tile-making machine and watching the soft clay squeezed out into a tile—just as one would make big hollow sausage—than I was by the drainage; but I came to realize how large was the number of tiles manufactured.

In the part of Kansas where we lived, there was not much swampy land to drain. On our farm, a "dead furrow"—a sort of ditch made by the plow only—was often sufficient to drain the lower-lying land. The creeks furnished most of the the water persisting through the summer and autumn. A Kansas creek hardly resembles a New England brook; it is rather a long narrow pond interrupted by swifter, shallower stretches known as "riffles," which in late summer often disappear, leaving simply a chain of disconnected ponds. We were not looking for anopheline larvae in those days—catfish held more of our interest—but doubtless they were present. I have found them in similar log-filled waters in the common creeks of Mississippi. In Kansas we lacked the alligators among our creek fauna, I am sure of that.

These creeks were mostly wooded. Later much of the woods was thinned or cleared away to make more room for planting. In

some localities the breeding of dangerous species of mosquito increased when the sunlight was introduced; but with us the malaria period and the more wooded period came at about the same time. Probably our woods were never thick enough to interfere greatly with mosquito breeding.

Branches of the streams often extended into the prairie. Along these the woods were often sparse, consisting only of some pioneer clumps of willow, button bush, and plum, hardly thick enough to shut the sunlight from the water. In these branches permanent water lasted through the less droughty summers, and they may have had something to do with the production of anopheles, especially since they contained less muck and vegetation than did the shaded ponds. Too much mud and debris may interfere with the breeding of certain anopheles, especially of the more dangerous kinds. In India, for example, *Anopheles culicifacies* prefers the new, rain-filled waters to the ancient "tanks," ponds often clogged by mud and vegetation.

Dr. A. E. Hertzler, whose malaria practice in central Kansas I have mentioned, is of the opinion that the buffalo wallows, abundant there when the country was new, may have been an important breeding place for malaria-carrying mosquitoes. At all events, when the prairies were plowed the malaria disappeared. In this case, surely, one cannot blame the "newly turned soil," often dreaded by the pioneers as the chief cause of malaria.

In our part of Kansas one type of pond increased when the prairie was fenced and the primitive range was cut up into pastures. Animals, which formerly roamed far to seek water holes, were now pastured, and their drinking water had to be provided by artificial means. This was done by shallow ponds constructed in the following manner: the dirt in the bottom of a slough was scraped out and piled into a sort of dam spanning the lower end of a considerable cavity. With the first heavy rain this cavity was filled and enough water was impounded to last all summer. When new, these ponds furnished the farmer boys with famous swimming places, but later they filled with muck and vegetation and were then more frequented by turtles, snakes, and water-loving

insects. Lucky it was that we were not invaded by *Anopheles gambiae*, as Brazil was in later years, for this mosquito delights in the muddy track-pools made by animals at the margin of water holes. Our ponds never seemed to become breeding places of dangerous malaria-carrying mosquitoes, however popular they became for other kinds. And, while the rural pond-area, especially in the neighborhood of dwellings, was increased by these ponds, it is doubtful if they had much to do with malaria. At all events, malaria remained in the bottom lands and did not follow the settlers into the new farms on the prairies.

The United States is a country of vastly varying terrain. In some localities, as in the prairies of the Middle West, all the settlers had to do was to plow the treeless land in order to make usable farms; while in another locality, woods had to be cleared and stumps grubbed out before the ground could be profitably plowed. In one region great canals had to be constructed and ditches put in; in others, as on our farm, very minor drainage sufficed. Often none at all was needed. In all or in very many of these localities, malaria was prevalent in the early times, while in all, or at least most of the more northern, it nearly disappeared as the country grew older. The anopheline mosquitoes were there when the country was new and myriads of them are present still. It is hard to assess the weight of agricultural drainage in malaria reduction.

The problem seems still more puzzling when we consider certain localities where anopheline breeding was increased by the development of agriculture; I refer to lands which have been flooded and converted into rice fields. Such rice-growing lands are found in parts of Arkansas, Louisiana, and the alluvial plain of the Mississippi River, to mention only those in which I have had some experience in anti-malaria work. In the farms of these areas, as well as in the country towns adjacent to them, I have seen literally myriads of *Anopheles quadrimaculatus* crowded into dwellings and stables and under bridges. Sometimes the ceilings of houses were almost black with them, and unless dwellings were properly screened they were almost uninhabitable. Even the dead were

not spared. I once found the mummy of a dead cow harboring many hundreds of them—the sort of shelter in which Virgil found the Roman bees. Yet in none of these localities did I find malaria particularly abundant. At Ellsberry, Missouri, situated about sixty miles north of St. Louis, rice had been cultivated for years in the rich bottoms of the Mississippi River. In 1925, we examined the blood of many children there, white and colored, in town and country, and found not a single specimen with malaria parasites. If one may judge from the testimony of physicians, malaria had been abundant there in earlier times, but had died out and had not reëstablished itself when the introduction of rice-growing brought in innumerable anopheles.

In the neighborhood of the rice center at Stuttgart, Arkansas, some malaria was present at the time of my first visit there in 1920; and an occasional mild epidemic had been noted by physicians. But our survey of blood specimens of school children within the rice-growing area showed a lower parasite index than that in schools located outside of it. About 1943, a blood parasite survey of people in the neighborhood of Army camps near rice fields showed hardly more than one-half of one per cent positive. It is true that the greater use of remedies against malaria may affect the parasite index of people in this country. But this figure may be contrasted with the indexes occurring in a really malarious country like West Africa or Macedonia, where I have found localities with indexes of ninety per cent or higher.

In the rice country of southern Louisiana malaria is even less prevalent than in that of Arkansas. About 1923, we had a laboratory at Crowley for malaria investigation. When we needed mature specimens of *Anopheles quadrimaculatus* for working material, we had only to send out to the barn for them; often we found an abundant supply under the veranda or beneath the doorstep. But there was too little malaria in the vicinity to make malaria research worth while, and so we packed up and moved to a more promising locality.

One finds in eastern Arkansas two regions which offer an interesting comparison with respect to malaria, regions which, by

the way, occupy different sides of the famous Crowley Ridge; this, geologists tell us, divided in Tertiary times the alluvial valleys of the Mississippi and Ohio rivers. In certain large areas of the Mississippi bottoms situated on the east side of this ridge, extensive drainage was undertaken some years ago to improve the land for cotton cultivation, not primarily to get rid of malaria. But when the swamps were drained, many mosquito-infested lowlands were permanently dried and anopheles greatly reduced. In a region on the west side of the ridge (in the flat plain of an ancient river valley), rice cultivation was introduced and the number of anopheles greatly increased; but in both east and west regions malaria decidedly decreased. How can we explain the apparent anomaly?

I believe that we find the explanation in the character of the populations of the two regions. In the cotton region, large numbers of small renters lived on farms where they were poorly protected against mosquito bites and often received scanty treatment when ill. The reduction of anopheles counted a great deal with these people. In the rice country, people were far more prosperous; they were well screened and otherwise well cared for, and their economic condition was such that they could afford adequate treatment when ill. Owners commonly lived on their own estates; but Negro farm hands, when employed, were encouraged to live in towns. The bedraggled huts so commonly seen along the bayous in the cotton country were comparatively rare.

Probably an improvement in the economic conditions of a people would not account for so much malaria reduction in the presence of a more effective anopheline. If *Anopheles gambiae* were bred in half the numbers of *Anopheles quadrimaculatus* in the rice fields, I doubt if any ordinary screening or malaria treatment would adequately cope with it. But with the species of anopheles prevalent in this country, I believe that the economic status of the people in the rice-growing country best explains their low malaria index in the presence of such intensive anophelism. I doubt if *Anopheles quadrimaculatus* has undergone through breeding in rice fields any biological change which might impair

its ability to transmit malaria. I once tested some specimens on a malaria carrier, and they became infected much as do members of this species when bred in waters far away from rice fields.

It was Ziemans, I think, who first formulated the statement which may be freely translated, "Malaria is a disease of defective civilization." One might accept this dictum with an amplification of the term "defective," making it "defective in the means or inclination to combat malaria." And the inclination may depend on the amount of knowledge a people possesses of the way the disease is transmitted as well as on their economic status.

I do not propose education and improvement in economic status as a substitute for drainage and larvicides. There are localities where there is no time for such improvement, or where for other reasons it is impractical. But I believe that social betterment is a valuable aid in promoting any anti-malaria work, and may be the only thing to do in places like our rice fields, where anophelism can hardly be prevented. Surely a prosperous people can afford proper screening—an excellent measure and the nearest thing to a panacea for malaria prevention that we now possess.

The relation of irrigation and malaria is illustrated by another example taken from Dona Ana County, New Mexico, where I worked during the summers of several years. Here the increase of anopheles through irrigation was promptly followed by an increase in malaria. At first the irrigating water was simply applied to the land by means of canals leading from the Rio Grande River, but the land became nonproductive on account of the accumulation of salts deposited by the evaporation of the mineral-laden water. A similar trouble has for centuries beset the lands in many dry, irrigated countries; and the difficulty has been met in different ways. In some localities in Egypt, water from the Nile is flooded over a field and held there for a time by dykes. It is then released, and as it flows away carries with it the soluble salts, thus literally washing the ground. In New Mexico, huge drains were constructed so that when the water from the river had furnished its moisture to the land, it was drained away and not allowed to evaporate and leave behind it the salts to poison the soil. But the

drains became full of willows, algae, and other aquatic or semi-aquatic plants, which, growing in the cool clear water, formed excellent breeding places for *Anopheles maculipennis*, a close relative of the chief malaria-carrying mosquito of many parts of Europe.

Because of this increase in anopheles, malaria invaded that part of New Mexico in the middle 1920's, soon increasing to epidemic proportions. The disease was new to a large percentage of the population. There is indeed a tradition of a malaria epidemic along the Rio Grande some fifty years previously; I talked with an old inhabitant who claimed that he himself had been a sufferer. This epidemic may have been caused by an unusual drought, which occurred then and reduced the river to a chain of pools favorable for mosquito breeding, a condition which did not long persist. At all events, by the 1920's a new generation of people had arisen, most of whom had never had experience with malaria, and were unfamiliar with its treatment. One is reminded of the Acadians when they arrived in a malarious region in Louisiana. They found a kind of disease not amenable to any charm, not even to "wearing a spider hung round one's neck in a nutshell."

During the early period of the epidemic, people in Dona Ana County occasionally lay sick for days with little or no treatment, a lasting source of infection for anopheles. And these people with no previous experience of the disease had little or no tolerance of it. I saw, in one morning, nine persons sick abed, all with the parasites of tertian malaria in their blood. In Equatorial Africa, one would rarely find that much malarial sickness, at least not among adults, even if one took many trips in search of it. It would be easy to find people with abundant parasites in the blood, but African adults have long become accustomed to malaria and tolerant of the effects of the parasites.

The New Mexican epidemic was brought under control by treating and educating the people, and by destroying the larvae of the mosquito vectors in the drains.

In northern New Mexico I had opportunity to study another interesting situation. Here malaria had been endemic for many

years. A Dr. Livingstone, one of the physicians of the region in the early days, graphically described to me his cases of malaria. They came by wagon loads, some of them from the high regions at Dixon, New Mexico, bouncing over the mountain roads and "chilling" at every jump. At Espanola they thronged the doctor's yard, waiting their turn for attention. They seemed to be far wiser with regard to the treatment of malaria than the people in some other parts of the state, for example those we found lying sick with no treatment at all. When, in the 1920's, we began work in northern New Mexico, malaria had decreased somewhat, but there was still plenty of it. We found blood parasite indexes of twenty-five percent or more among village children, some of them Pueblo Indians. The ancestors of these Indians had lived in that region for centuries, but malaria may have been, comparatively, a newcomer. Anyhow, everybody suffered more or less—Indians, Spanish-Americans, and Anglo-Saxons.

The anopheles which produced this malaria came from two sources: the Rio Grande itself and the lands irrigated by it. Like most rivers not confined by rocky barriers, the upper Rio Grande is continually changing its course. (Incidentally, it often changes its color; one day it is light gray and the next a chocolate red, depending on the color of the soil where a heavy rain happened to fall and flood the river.) Sometimes the river would flow on the right side of an island for years, then change to the left, leaving its former channel as a sort of elongated pond or lake. Its waters remained clear and overgrown with aquatic vegetation, furnishing an excellent breeding place for anopheles. Again, much of this semiarid region is irrigated. Often a whole pasture or meadow is partly inundated during a period of many weeks, and the cool, clear water flowing slowly through these grassy places forms favorable breeding places for *Anopheles maculipennis*. Thus an abundance of malaria-carrying mosquitoes were not wanting. I have often found adult anopheles in very large numbers in that region, especially in shelters near the "wet pastures."

The Pueblo Indians there knew what to do for chills and fever, but were not particularly well informed regarding the man-

ner of malaria transmission or prevention; and one of our duties was to spread as much of that knowledge as we could. I remember lecturing on malaria to an Indian audience, with a kindly merchant of the village acting as an interpreter. After the lecture, opportunity was offered to the Indians to ask any questions. I had mentioned ditching as one method of malaria control, and an Indian, evidently a man of age and experience, asked if the Indians might not themselves get malaria while digging the ditches. My best answer was that the Indians would be safe if they dug the ditches during the winter. I had described how malaria is carried by mosquitoes and mentioned the fact that certain larva-eating minnows, like *Gambusia*, were very efficient in destroying mosquitoes. My questioner decided that after all it might be best to use the "little fish" to do away with the malaria-spreading *animalitos*. From results, it appeared that the Indians of this pueblo decided to leave the work to the fish and not to bother much about ditch-digging. The beavers of the neighborhood were likewise careless of antimalarial engineering; indeed, they had the habit of undoing drainage by constructing dams. They were quite willing to work but only according to their own plans.

The *Gambusia* minnow had already been brought into southern New Mexico and we introduced it into the region of the upper Rio Grande. There it multiplied abundantly and proved to be a good antimalarial measure; at all events, there was a sudden drop in the malaria index after our fish-spreading, especially in the pueblo where the Indian counseled the use of the "little fish."

Gambusia minnows seem to spread particularly well when first established in a country; for, like many plant and animal pioneers, they find in a new abode more abundant food or fewer natural enemies than they do in their home environment. The manner of artificial spread of this minnow is simple: one chooses for a breeding place water provided with large springs so that it will not freeze in winter nor dry up in summer, and possessing some very shallow places where the minnows may escape the larger fish, their deadly enemies. When a colony is well established, one transports specimens to the mosquito-breeding waters. Auto-

mobiles are very convenient for this purpose—the car affords rapid transportation, and a spare tire may be inflated and used to store a supply of air, which is slowly bubbled through the fish container to give the minnows abundant oxygen during the journey. These minnows are born alive, often scores of them in one family, and multiply very rapidly; the offspring of one individual may number several thousands in the course of a season.

Gambusia minnows are very efficient in destroying larvae, beginning their attacks when still of that small size described by Dr. Henry Carter as consisting essentially of "two eyes and a tail." They often creep through aquatic grasses infested by mosquito larvae and clean out practically all of them. But the minnows have one great drawback: if the anopheline larvae feed quietly among horizontal grasses, algae, or other vegetation, as they frequently do, the minnows may leave them untouched. If something stirs up the larvae so that they wriggle over the surface, the minnows quickly dart at them. One observes the same behavior among large predatory animals: the prey may escape if it lies perfectly still.

One wonders if it might not be possible to improve a race of *Gambusia* so as to make the minnows more enterprising in their search for larvae, perhaps by encouraging them to swim around and disturb the surface of the water in such a way as to stir up anopheline larvae and make them more conspicuous. One can by selection improve the races of plants or animals more primitive than fish. It is possible that *Gambusia* is also educable, especially in respect to an accomplishment which might greatly increase its food supply.

So much for minnows as agents for destroying mosquito larvae. Another method is the use of chemical substances to kill them. An example is an oil, like kerosene, commonly used by spreading it on the surface of the water infested by "wrigglers." The way these oils work is not by smothering larvae, as might be done by covering the water with some air-excluding substance, but by poisoning them. Another class of larva-poisoning substance is exemplified by Paris green. This reagent occurs as a green powder

long used as an insecticide and as an ingredient of paint. Paris green is heavier than water, but when it is projected in the air and allowed to settle on water in the form of a fine powder, most of it will float because of its support by the surface tension of the liquid, much as a steel needle will lie on the water surface if carefully lowered on to it. Anopheline larvae feed in a peculiar way: the larva lies nearly flat on the surface of the water and, by means of special brushes attached near its mouth, starts currents on the water surface which carry all sorts of floating debris to the larva mouth. If the debris consists of particles small enough to enter the mouth of the larva and is not distinctly repugnant to it (as a droplet of some smelly oil might be), the particles go directly into the larva stomach. This debris might consist of dirt or sand which could be of little use as food to the mosquito, or it might be largely microscopic plants or animals which are its chief provender—it all goes down to the stomach. Crystals of Paris green, a deadly poison, will often be ingested in such quantity that the body is green with it. This indifference of the mosquito larvae to the quality of the things they are willing to swallow is thus utilized to poison them. If rats were so "easy," we might more successfully control them.

This method of poisoning larvae was first used by Roubaud in France, who employed paraformalin in dust form; then we used the same method with Paris green as a poison. Paris green is cheap, very toxic to larvae, and universally obtainable; and it has proved a very useful method of combating malaria-carrying mosquitoes. Now the new larvicide, DDT, or some other chemical may replace both oils and Paris green as mosquito larva killers.

People often associate malaria with stagnant water, steamy swamps, misty lowland, and masses of decaying vegetation. While the disease is sometimes found in such surroundings, it is by no means exclusively so. In northern New Mexico, we found severe malaria associated with clear water, high elevation, and a dry, cool climate over the greater part of the year. Espanola, New Mexico, our headquarters during several seasons, is nearly 5,500 feet above the sea, and in adjacent localities malaria formerly pre-

vailed up to 6,000 feet. We find elsewhere in the world malarious regions of much greater altitude. Elevation alone cannot be counted on to prevent malaria, unless it be associated with temperatures too low for the maturation of the malaria parasites in the mosquito.

Climate, elevation, and unruly rivers are hard to mend; but we can prevent much malaria by a proper use of irrigating water. Our aim should be to use most of the water for the plants and as little as possible for the mosquitoes. In New Mexico, as in many countries, the waste or maldistribution of irrigating water is not uncommonly followed by disease among the people. Irrigation is a major problem on this planet; it is imperative to learn to irrigate without breeding pestilence.

In comparing the factors which contributed to the decline of malaria in the United States, we find it difficult to say which is of most weight; for they vary greatly according to time and locality. In one region malaria diminished when the land was drained, in another when it was flooded and devoted to rice cultivation; in a third when the woodlands were cleared, and in a fourth when an almost treeless prairie was cultivated. Common to all these changes was an almost universal improvement in the way of life of the people which brought with it more screens, more quinine, and more doctors to prescribe quinine. Better food and housing which followed the development of the land certainly helped people to resist all manner of disease. In many localities, usually in more recent times, conscious measures such as anti-malaria drainage and insecticides contributed to the decline of the disease. But considering the great bulk of the decrease in malaria which has been noted all over the country, from the Great Lakes to Texas and through many years, I am inclined to give the greater credit to screens, quinine, and improved medical treatment.

Some localities in this country have lagged and we know there are many countries where climate, lack of wealth, and more dangerous mosquito vectors will make more direct anti-malaria

measures necessary. We cannot expect everywhere such strong tendencies towards a "self-healing" of malaria as have prevailed in the United States.

The second world war has newly brought to America the problem of the possible increase of malaria through the numerous parasite carriers among soldiers returning from the South Seas or other malarious regions. How great is this danger and how may it be avoided? Several considerations seem pertinent:

First, the introduction of malaria through war is no new thing. We have illustrations in the return of soldiers after the Civil War, and in some countries, notably Germany, after World War I. In Germany, at least, where the new foci were well studied and preventive measures taken, no permanent increase of the disease followed. And it is harder for malaria to get a foothold in this country than it was a generation ago. We are better screened and better provided with medical treatment than we were then, and our knowledge of the disease and its prevention has greatly increased. Our country, in respect to epidemic malaria, may be compared to a modern fireproofed building which has become slow-burning; although a fire may get started within, it does not spread into a wide conflagration.

Again, our organized medical service has improved. It ought to be possible to list every case returning to our shores, and to see that it is cured; or, if this is not possible, that a relapse is properly cared for. And we see how the number of cases of malaria among our armed forces decreases as the technique of protecting troops in malarious countries improves.

Many anopheline breeding places in this country may be abolished, especially as we now have improved methods of dealing with them; but it seems to me that the emphasis should be placed on the human factors, the care of the sick and the screening of the well. Anopheles are widely distributed in this country, and they are abundant in places without malaria; I doubt if there is a rural county in the United States, except some high mountain or desert localities, where anopheles cannot be found; yet in comparatively few counties does serious malaria exist. It would

be a great task, and I think an unnecessary one, to attempt to "de-anophelize" any county-wide area of the country. The funds needed for such an enormous task might be spent for some better purpose.

Another consideration seems of much weight. We know that malaria has greatly decreased in this country. During the earlier years of this decline, there must have been countless human malaria carriers; yet despite their presence, malaria continued to decrease. It would seem, then, that the importation of a few hundreds of carriers from the South Seas or the Orient should not lead to a dangerous increase in malaria, especially since we deal with soldiers who receive proper medical attention. Probably few of the indigenous carriers of the United States in the earlier years enjoyed such good care.

In the United States, the mosquito carriers are relatively less dangerous, and screening is almost universally used. There are other countries, those in southern Europe, for example, where post-war malaria may be a far more serious matter.

CHAPTER TWO: CENTRAL AMERICA AND THE WEST INDIES

Since the winters in the United States were rather cool for anti-malaria work, we used to pack up our apparatus and move south to Central America and the West Indies for the winter—like migratory fowl, except that those fortunate creatures do not have to pack up. During our sojourns in the south we were usually the guests of the United Fruit Company through the invitation of its then medical director, Dr. W. E. Deeks, who was naturally much interested in the "chief headache" of the plantations, malaria. The Company took good medical care of its employees, supplying them with hospitals well staffed with physicians, at that time mostly "States" doctors but including some young "medicos" from Europe. There were always plenty of malaria patients in the hospitals, and the Company furnished us with laboratory room; so we had an excellent place for the study of malaria in the tropics.

The employees in Central America were chiefly Spanish Americans and West Indian Negroes. The Negroes seemed to suffer less with malaria, although often infected with parasites. In one plantation, where we helped survey the Negroes for malaria parasites, those who were found to harbor them were taken to the hospital for treatment. The trip to the hospital was something of a lark—a free ride on the Company train and a chance to wear holiday clothes. I never saw a group of people more eager to be "juked," that is, needle-pricked, for a drop of blood. One had to look out lest the same person came up to be juked twice, so eager were they to be found positive.

The warm climate and the abundant rainfall of the American tropics favored the proliferation of anopheles; and one of our activities was to survey the terrain for the breeding places of malaria-carrying mosquitoes. The most dreaded there was *Anopheles albimanus*, which could breed in temporary rain pools as well as in more permanent waters. Since rain pools are ubiquitous

during the rainy season, this mosquito enjoys a peculiar advantage; the eggs may be laid in the shallow pools adjacent to a native house, where they hatch, their larvae develop and pupate, and the adults emerge ready to move into the human habitations.

The abundance of *albimanus* aided us much in one piece of research we did on a United Fruit plantation in northern Panama, a bit of research which I briefly describe. About that time some new synthetic anti-malaria drugs, particularly plasmochin, were receiving much attention. Quinine can be successfully grown only in certain parts of the world, especially India and Java, and it would be very desirable to make this drug, or some substitute for it, synthetically; then it could be manufactured in any quantity and in any convenient chemical factory. Plasmochin was not the chemical equivalent of quinine, but it promised to cure the disease. In one respect it excels quinine—in its ability to kill the mature male and female parasites of "tropic" malaria, or at least to render them innocuous; a valuable quality, for thus plasmochin given to patients might not only assist in their cure but also prevent their parasites from infecting mosquitoes. One took the medicine for his neighbor as well as for himself.

Our task was to determine the minimum dose of plasmochin effective on the mature malaria parasites. It was important to test small doses, for, unhappily, plasmochin is not so harmless as quinine; larger doses are often toxic to patients. Our idea was to emasculate the parasites without harming the patient. The first thing we had to do was to find a person harboring mature parasites. One would think that an easy task when hospital wards were full of malaria patients, but it was not so simple. Many patients did not have mature parasites, while others had them in numbers so small that they did not adequately infect the mosquitoes. Again, although mature parasites were plentiful enough, either the male or female parasites might be lacking; there was not a proper parity of sexes. So the patient had to be tested to see if he was an effective carrier. That had to be done by feeding mosquitoes on his blood and then dissecting them to see if oöcysts of malaria had formed on their stomachs. Not every kind

of mosquito would do; we needed a supply of *albimanus*, which we knew to be an effective malaria vector. We had no insectary; so we had to scour the countryside for specimens of *albimanus* of sufficient maturity: usually only those about to emerge were considered good material. To discover and collect these larvae or pupae meant hours of dipping in pools, bayous, and ponds; a batch of a hundred was considered a good day's work. From these insects adults were bred out and were used to bite the patient.

If the patient proved to be a suitable parasite carrier, he was given a tiny dose of plasmochin, first being weighed so that the dosage could be reckoned as so many miligrams to a kilogram of patient's weight. Then after time was allowed for the drug to act, the patient was again bitten by *albimanus*. If any of the mosquitoes got infected, we knew we would have to increase the plasmochin dose, if the patient were to be "sterilized" of viable parasites. It was determined that a plasmochin dose unbelievably small, in one case of only one-half centigram, might harmfully affect the parasites. And a whole centigram is considered a safe dose for the patient.

The mosquito-collecting excursions were always interesting and sometimes afforded a tinge of adventure. One of my choicest *albimanus* collecting grounds was a large bayou said to be infested by alligators. I was told that these rarely attacked a human being but were especially fond of dogs; so I collected freely in this pond but never took a pet dog along, for the alligators might be well disposed toward me, but, careless in their table manners, take a bite of both master and hound. Occasionally I would stir up one of the large, alligator-like iguanas, common in that country, but they never even threatened to bite.

One often had to dip pools in a pasture, where it was always worth while to keep an eye out for dangerous bovines, but I was hardly ever disturbed by them. I have often been stared at by both man and domestic animals—it is very interesting, I presume, to see a person going about dipping up something with a white pan, taking it out of the pan with a medicine dropper, and de-

positing it carefully in a glass container. I remember once I happened to look up while dipping in a pasture pool and found myself surrounded by a ring of horses, making no sound but earnestly staring at my every move.

One would expect domestic animals to be more sophisticated in a country where mules were supplied with bathtubs and fed on bananas. This was literally true in one pasture I visited, although the bathtub was an old one used for a drinking trough, not for ablutions. But the bananas were real; they were the ones which came from bunches rejected at the landing wharf because irregular or too small for marketing. But they often contained perfect fruit and were taken to the pastures and fed to animals.

Another collecting place of interest was the island of Carinero, situated in northern Panama just off the town of Bocas del Toro, the "Mouths of the Bull." I presume the bull was just a name taken from some topographical peculiarity of the coast, for a real bull would have found it too uncomfortable to remain there, because of numerous *albimanus* mosquitoes which flew over in quantities from the island to Bocas, spreading malaria in that city. Undoubtedly they took the precaution to load up with malaria before they flew over, for there was a malarious village on Carinero very convenient to the breeding place. It is said that the name "Carinero" comes from the circumstance that Columbus keeled his ship there to clean its bottom. If malaria were as abundant there at the time of his voyage as it is now, Columbus might have had to make a longer stop, and that for hospitalization, before he left the Spanish Main. I mention this island malaria to correct an idea, still extant, that a sea breeze prevents the scourge —possibly a notion perpetuated by the ancient misnaming of the disease ("malaria"—"bad air"). I wonder how many evils in the world have been influenced, perhaps increased, by the names people have given them!

One hears much about tropical jungles and the dangers sometimes associated with the tropics, but in Central America we found the dangers remarkably few. I would reckon Almirante, the United Fruit Company center in northern Panama, as one of

the most healthful places I know. Of course, the Fruit Company did much to make it healthful; the coast of that country was far less healthful a century ago. At the time of our visit this place was comparatively free from automobiles, which afford one of the greatest dangers to life and limb in localities where the roads swarm with them. To those who had to travel a good deal in that region, there was a greater danger than automobiles even—the railway motor vehicles. I have spoken of hospital beds full of malaria patients; it was wise to reserve a bed or two for people injured by these motor vehicles which were so light that they might be derailed by collision with an animal, domestic or wild. We know how animals always think that the other side of a road is much safer than the one they happen to be on when a vehicle comes rapidly by—a delusion sometimes shared by human beings —and I suppose it is especially strong in jungle animals when the car passes at night. It is said that even large snakes may venture an untimely crossing and derail a car. I myself have suffered three derailments (none from snake collisions), and a number of narrow escapes, but never got bruises worse than those I have experienced after a class football game in college. If I had collided with a fallen tree, as sometimes happens when one rounds a curve at full speed, I might not have got off so well.

It is the unaccustomed peril that terrifies. If one graded the automobile danger at fifty, that of wild animals might be only a fraction of one, and that of tropical disease in some Fruit Company towns hardly more. But these are the dangers that the newcomer to the tropics most dreads. At our bathing place in Almirante we had both sharks and barracudas, the man-biting fish of these waters. I presume the barracudas were really more dangerous than the much-publicized sharks; we did not mind either of them much.

In the West Indies we visited principally the larger islands, Haiti and Cuba. The inhabitants of Haiti had lived for centuries in America, long enough to forget much of their ancient African tongue and acquire a French patois, and long enough to learn to govern themselves in a republic; but not long enough to cast off

their original stock of African malaria parasites. At all events, we found these in about the same kinds and proportions as I have found them in West Africa—three-fourths of the species *falciparum* and one-fourth, *quartana*, with only a scattering of *vivax*. We examined blood specimens of hundreds of Haitians then being recruited for cane cutting on the sugar plantations of the United Fruit Company in Cuba, for at that time Haiti did not furnish enough labor for its inhabitants and many sought employment abroad. Like so many sea-girt islands, Haiti was not lacking in productive soil so much as in rainfall. Possibly by this time the ancient French irrigation projects have been repaired or renewed, and new plantations and new malaria problems are furnished to the people.

I have mentioned species of malaria parasites, and I interpose here a short description of them. There are four well-defined species, and many varieties some of which are not yet well classified. I speak only of human malaria, not including the species and varieties of malaria among lower animals, and I shall not attempt a detailed description of even the human species, but will mention only some of their more prominent characteristics. *Plasmodium vivax* is the species more often associated with a regular every-other-day fever. It is also known as "benign," but it may cause a severe illness or death. It usually yields to quinine or other antimalarial drugs, but likelihood of relapse is greater than with some other species. It is the kind most commonly found among white people in the United States.

Plasmodium falciparum, "the sickle-former," is so named because of the sickle form of the mature female parasite. In America it is often called the estivo-autumnal form, because it more commonly appears in the late summer or autumn. Other names are also more or less descriptive: "tropical" because it is very common in the tropics, and "perniciosa" because it is often associated with very severe illness, like cerebral malaria or blackwater fever. It is the form most often found among Negro patients in the United States.

Plasmodium malariae is commonly called "quartan malaria" because the paroxysms typically occur every fourth day instead of every third day as in the case of *vivax*. Its manifestations are usually milder than those of the other species. When malaria is diminishing in a population as the result of a long period of non-transmission, quartan is often the last species to yield. It occurs in a very small percentage of the cases in the United States, but seems to persist decade after decade, even when malaria generally has fallen to a very low level there.

Plasmodium ovale, the fourth species, is very rare in the countries in which I have had experience; I have seen but little of it.

After an attack of malaria the patient enjoys a certain amount of immunity to infection by the same species or the same variety which caused his illness, but to a much lesser degree, if at all, to another species. There is not much hope in the plan which has been proposed, that one should "vaccinate" himself by means of a light attack of benign tertian and thus be free from all manner of attack. Such a procedure might be of some use in a country where there is only one species or variety of *vivax*, but would hardly do for localities where there are several species and many varieties.

The physical condition of the person contracting malaria has much to do with the severity of the illness. We often hear of people who have contracted "a tropical fever" somewhere, as if an especially virulent form of the disease were confined to certain localities. The virulence of the attack is often the result of the susceptible condition of the patient or perhaps of the size of the infecting dose injected by the mosquito, as well as of the species of malaria parasite. One may have a "congestive chill" and die in Kansas or in the tropics. Much attention is now being given to the subject of immunity from malaria, and the new knowledge may upset some of our old conceptions.

We followed our people and their malaria to eastern Cuba, where both were present in abundance. But the most severe malaria occurred among the native Cubans; possibly they have less

tolerance of the disease than their negroid neighbors. I mention two incidents in Cuba: One had to do with a medical officer we knew who used to administer free quinine to the people in his clinic, always given by syringe, intramuscularly. We asked him why he did not make the people swallow it, a method just as effective for his kind of patient and much more convenient. But, he said, unless he gave "shots" nobody thought he was really doing anything, and people would not come to the clinic. Human nature is much the same everywhere, particularly in the belief that there is some special magic in a glass syringe.

The other incident had to do with blackwater fever, an especially malignant form of malaria formerly common enough in the United States but now, with the diminution in estivo-autumnal malaria, happily much more rare. An outstanding symptom of the disease is the presence of hemoglobin in the urine. In Cuba we visited a family reputed to have had twenty-one cases of blackwater. They must have doubled up some way, one member of the family having more than one attack, else there would not have been enough children to go around, although the house was full of them. Possibly there was some quality of the blood or other physical characteristic common to all members of the family, which made them peculiarly susceptible.

The West Indies, like a lesser Oceanica, has islands apparently malaria-free; their freedom often depending on a lack of anopheline vectors of a more dangerous kind. There is now so much rapid transportation among these islands and from South and Central America, that, unless airplanes are effectively disinfested, we may expect a far wider distribution of the vectors of malaria and perhaps of jungle yellow fever in this region.

CHAPTER THREE: THE PHILIPPINE ISLANDS (1)

My chief concern in the Philippine Islands, where I worked during the period 1911-1915, was bacteria in human disease; and I presume I was hired for that study alone by the Bureau of Science at Manila, which employed me. But I eventually got interested in malaria and added it to the list of microbes I was studying. And why should one stick closely to one sort of microbe? They often hunt human beings in pairs or in packs of two or more kinds at once, and it would appear to be logical to hunt them in the same way.

Manila itself would seem to be a good place for a study of the transmission of malaria by anopheles. It lies at almost sea level and is in the neighborhood of rice fields and other feeding places of the larvae of anopheles; we used to find them just across the street from the house where we lived. There were people enough in Manila both to transmit malaria to and to get it from; for hundreds of persons came into the city with malaria parasites in their blood. But there was little if any transmission of the disease in the city. Why this apparent anomaly?

The answer is that although there were many anopheles bred in and around the city, they were not the right species for transmission. Anopheles vary much in their malaria-carrying ability; those breeding in the rice fields near Manila were mostly *Anopheles subpictus*, a very poor vector of malaria. Mosquitoes of this type are susceptible to the disease and may be made to transmit malaria under artificial conditions; but they are little disposed to bite human beings, preferring domestic animals. A common farm animal in the Philippines is the carabao or water ox, an animal which has been aptly compared to a grand piano—so broad and squatty it is. It is very calm and lethargic unless deprived of its daily mud bath, and offers an excellent feeding place for mosquitoes; for what sensible anopheline would seek the blood of a restless and slapping human being when the back of a carabao offers a broad, fertile area, where a mosquito may feed as calmly as

flies on a syrup jug? Domestic animals neither give nor receive malaria—that is, malaria of the human kind; so *subpictus* and its rice-field associates near Manila have little or nothing to do with the transmission of malaria.

One of the first antimalarial undertakings by my colleague, Dr. Ernest Walker, and me was to determine which of the many species of anophelines in the Philippines is the chief vector of malaria there. One species known to be an efficient carrier in Malaya was found, but only in relatively small numbers and not particularly associated with endemic malaria. Other species came under suspicion, among them a certain variety of *Anopheles minimus*, widely distributed and occurring abundantly in localities where malaria was endemic. We collected large numbers of these and whatever other anopheline species we could find, including the *subpictus* common in the rice swamps. We usually collected them in their aquatic stages and bred out the adults in the laboratory. In this way we ran no risk of confusion with specimens already infected in nature, for only the blood-seeking adults ever contract or transmit malaria. Then we sought human malaria carriers with sufficient mature parasites in their blood and allowed our various species to bite them. The blood-engorged specimens were preserved alive in mosquito cages, and after ten to fifteen days were dissected to determine the presence of malaria parasites. It proved that the proportion of *maculatus* and *minimus* malaria-infected was very high, while that of *subpictus* and other rice-field mosquitoes was very low, almost lacking. So we concluded that the variety of *minimus*, susceptible and abundant, was the chief carrier of the islands, a conclusion amply confirmed by later observers.

We found our *minimus* easily identified in the aquatic as in the winged stage; the larva was small but broad and thick, reminding one of the head of a viper, and it was commonly variegated with black and white colors.

Anopheles minimus is rarely if ever found in rice fields of the Philippine sort, but is primarily a stream-breeder, preferring clear water flowing through the grasses, ferns, and other vegetation

overhanging the margin of a stream. So one would not expect to find it in the stagnant waters suitable for rice-growing.

A good example of one of its habitats is a stream far within the interior of Luzon known to the Filipinos as the "River of Death." This river was being bridged some years before I saw it, and numerous workmen were employed there. They built their shacks in what seemed to them particularly attractive places to live—the bed of the nearly dry stream right by clear, flowing water. Now this clear water was just the kind that *Anopheles minimus* had selected for its abode; and a very serious epidemic of malaria followed. I was told that at one time there were not enough people well enough to man the bridge-building. How much sickness and expense might have been spared if only the people had had a little knowledge of the relations of malaria and mosquitoes, and of the common breeding places of the evil sorts!

Another example of the association of this same species of anopheles and malaria occurred in the village of Santa Margarita in Luzon. When I was searching for localities especially suitable for the study of malaria, I was referred to this village as one where the death rate exceeded the birth rate, a relation not common in the Philippine Islands at that time. I examined blood specimens of school children and found sixty percent with malaria parasites; and these children were among those well enough to attend school. If I could have examined all the children of the village, well and sick, I might have found a much higher percentage infected. No wonder the place was considered malarious!

This village had a water supply not usual in the Islands; a canal connected a stream with a series of ditches dug along several streets of the town, thus affording an abundant supply of clear water right by the dwellings—an arrangement possibly introduced from some arid village in Spain. These ditches were open, sluggish in many places, and provided with grass and other vegetation overhanging their margins and extending into the water. Thus the bright, clear water with an abundance of larval food afforded an ideal place for the larvae of *Anopheles minimus*, and the occurrence of so much malaria in the village was explained.

I took a temporary residence in the village and made many mosquito surveys along the ditches. To the people, this dipping for *animalitos* in the water was a curious novelty. I was working along the ditches one day when the inquisitive crowd got inconveniently close. The village policeman, whose not overabundant English suffered from a slight impairment, thought his prerogatives were being interfered with and called out, "*I* am r-r-esponsible for him."

I was reminded of an anecdote told of Dr. Tuckerman, the famous naturalist and lichenologist. While he was scraping a tree one day in seach of his favorite lichens, a local dweller asked: "What's that fellow doing over there?" His neighbor answered, "Oh, he's all right. He's a natural."

Here in Santa Margarita as at the River of Death, a very little knowledge would have availed much. What was needed was to abolish the whole system of canal and ditches and dig a well or carry water from the streams as other people did. If for any reason this obvious remedy was impractical, the simple cleaning up of the ditches, freeing them from grass, and causing the water to run swiftly would have done away with the majority of the anopheles.

It takes two to make a parasite-borne disease, and the condition of the human carrier often has much to do with the matter. Such was the case on the San José sugar plantation in Mindoro, a spot whose early history was marked by many misfortunes. Shipwreck and cane-eating rats were among the first troubles (maybe the rats were the ones which left the sinking ship), and then came severe malaria. The doctor in charge of the plantation hospital told me that at one time the deaths were nearly twenty-five a month. Some fell unconscious in the fields—a phase of the disease popularly known as "Mindoro Lightning"—presumably a cerebral form of the malady, when the capillaries of the brain may become fairly clogged with parasites and death often results very suddenly.

Now the fatal cases in Mindoro oftenest occurred among immigrants from the Cuyos Islands, a small group of islands of the Philippine Archipelago, which may be remembered as the stop-

ping place of some of the refugees from Bataan during the recent war. The islands are healthful but not particularly fertile; therefore many of the young men go to other parts of the archipelago in search of work. Thus the population is so far depleted of males that, it is said, there are eight women to one man among the people. I stopped at these islands one Sunday and thought to confirm this remarkable story by a visit to the morning church services. And it seemed to be true, for the congregation was almost solidly women, all dressed in their Sunday black; and the only men I saw consisted of a narrow fringe grouped near the altar—quite properly under the eye of the priest.

Now many of these young men who go forth from the islands to seek work never return; and such was the case with many of those employed in the San José plantation. They were less resistant to the effects of the parasites of malaria because they had lived under relatively malaria-free conditions when they were growing up, and had acquired little or no tolerance of the effects of the malaria parasites. They were thus an easier prey to malaria than would have been the survivors in a village like Santa Margarita, the town of many ditches and abundant malaria. And the Cuyanos, had they known of their great susceptibility, might have sought a more healthful place for employment than on the ill-starred San José plantation.

Thus soldiers often suffer much from malaria when they are stationed in a malarious country. They may indeed be better protected from mosquito bites than are the people native to the country; but, once infected, they may suffer much because they have so little acquired tolerance of the parasites.

The San José plantation was well supplied with *Anopheles minimus*. I found a clear stream full of the larvae and numerous adults hiding under matted roots and in other shelters near the banks.

There was a tribe of semi-wild people, the Mangayans, settled in a part of Mindoro near the San José plantation. These I proposed to visit in order to take specimens of their blood; I wanted to see if they also had a large proportion of people harboring ma-

laria parasites. I had a half-breed as a guide and a Filipino companion, and for luggage transportation we had a carabao which we led or rode. It was an interesting route from the sugar plantation to the native village. Along the way were wild fruits sometimes identified by our guide. One I remember as a bland delicacy with flavor reminding me of a very economical apple pie. At the native village we proposed to hang around a day until word got about to the people that we wished to examine their blood. We slept the first night under a shack in the woods.

I feared that such wild people might hesitate to give up even a drop of blood, and so I had brought along presents to be traded for it. Each drop was valued at a square of cloth, appropriately red in color, with a handful of rice on top. I evidently overestimated the current price of blood, for by the second day we had people swarming around, all eager to coin their blood for cloth, rice, or anything else handy. When we left, anxious traders pursued us along the trail seeking further bargains.

They surely thought me "easy," for one of the men wanted me to give him the shirt I was wearing. I gave him the garment, first carefully notifying the Recording Angel that I had given a beggar the shirt off my back. I fear I did not add to the record that the shirt was soiled, that I had a change handy, and that it was one I had borrowed of Clark before I set out for the woods.

Maybe it was a punishment for this omission that a heavy storm came up and wet most of my precious blood specimens before I got them home. But I doubt if I would have obtained much valuable information regarding the question as to whether aborigines untainted by civilization carry malaria; there was too much contact with the Mangayans and white people. Since remote ages, merchants who set out to trade with primitive peoples have usually carried a supply of their own parasites, which they traded freely with those of the aborigines; and both of the high contracting parties usually held to the parasites long after the beads and whiskey had disappeared from among the wild peoples and the feathers and headdress had faded away into museums.

I saw another sort of anti-malaria work in the island of Palawan in the Philippine Archipelago—a long narrow island which points like a sword towards Sarawak in Borneo. Here we had to do with the prevention of the effects of infection rather than with a cure, and the means used was to cause the people to take small doses of quinine, daily or as often as convenient.

The people are of a peculiar sort, many of them "good time" convicts from the great prison, Bilibid, in Manila. When a prisoner had a good prison record over a sufficient period of time, he was removed to Palawan, where he might have a piece of land and even be joined by his family. At the time when I visited this island, about 1915, many of these paroled prisoners were in residence there; some of the servants of the officer with whom I lived were convicts. The convicts were "trusty" enough then, although later a group of them broke away from the reservation and caused some trouble among the people native to the island.

Anopheles minimus has no prejudices and bites convicts and keepers alike; and all had to be protected against malaria. The daily dose of "preventive" quinine was then called "quinine prophylaxis," now better named "suppressive" treatment because, although it does not prevent infection, it so favorably modifies the effect of the parasites that people can carry on without becoming seriously ill.

But the prisoners did not like to take this treatment under any name whatsoever, and resorted to various subterfuges to avoid swallowing it. So they were lined up by the prison officers when they were to be dosed, and after the drug was seen to go into their mouths, they had to swallow some water to insure that the quinine went down. Slippery elm, I believe, does not grow on this island.

How much malaria is now prevalent in the Philippines we do not know. Only this—that war and disease are ancient allies, and it is doubtful if the collaboration between them has been broken anywhere.

CHAPTER FOUR: THE PHILIPPINE ISLANDS (2)

Before concluding with the Philippine Islands, I shall digress for a moment to describe an experience not malarial but bacterial. I hope the reader will pardon the digression, for the experience was one of particular interest.

Far out in the "provinces," a local name for any part of the country outside of Manila, was situated an unusual farm. Unlike most of the farms in the Philippines, this one was isolated, the inhabitants not living in a village surrounded by many farms. And still more remarkable, the farmer was an American, living with his family on the land and using modern machinery and modern methods; something one would rarely find on a small farm in the Islands, where the tools and methods of their fathers were good enough for the Filipinos. It was a model farm—a bit of Iowa or Kansas set in the midst of the tropics.

The people on this American farm were hospitable and had many visitors, some of whom came for the hunting, which was good in that brushy neighborhood. But a curious and unpleasant thing often happened to these visitors. Shortly after their arrival, perhaps only a few hours after they had partaken of the ample hospitality of the farm, they were stricken with symptoms resembling those of cholera, and they then had to spend an unpleasant day or two, usually in bed. They recovered promptly and went on their way. The disease seemed to attack visitors only, the family suffering little or not at all. This trouble happened again and again, the attacks coming more frequently at certain seasons of the year. The family were naturally distressed, since their hospitality ended in acute misery for their guests.

The drinking water was at first suspected. It might be that there was some mineral poison in it, to which the family had become accustomed but not the visitors. Samples of the well water were sent to the Bureau of Science at Manila and analyzed, but no native arsenic or anything else could be found to account for

the illness. It was then examined for dangerous microbes. I myself had to do with this examination and could find nothing.

I happened at that time to be working on a disease of locusts—not one to cure them but one to spread among them in order to kill them. I used *Micrococcus acridiorum* of D'Herelle, a microbe which was reputed to slay its tens of thousands if one had a culture of sufficient virulence. And the way to heighten this virulence was as follows: A captive locust was infected in the laboratory by injecting a small dose of the culture into his body. When he died, which he usually did very promptly, one took a portion of his body contents and with it infected a second locust. This was continued up to thirteen transfers, when the culture should have attained a high potency. Then the micrococcus was transferred to a cageful of locusts, which, when dead, were scattered among a swarm of their fellows in the field, where the virulent culture was supposed to spread and decimate the whole swarm of pests.

Locusts commonly enter a neighborhood in great devastating swarms, feed full of what crops they most fancy, then take wing and fly to new pastures. It was hoped that they would take this micrococcus with them to infect new hosts and thus clear the whole countryside.

Now it happened that a swarm of locusts had invaded a certain area some miles from Manila and well out in the less populous part of Luzon. So I went out there with my virulent micrococcus to try it out on the locusts in the field. It proved that this locust-infested region was within reach of the cholera farm I have described. In an interval of the locust work, I decided to visit the farm and see if I could pick up any information on the ground. Since there were no finished roads or automobiles available, I traveled on horseback the sixteen miles out to the farm. Of course, like all visitors I was in danger of taking the disease myself, but I felt that nothing could hurt me: I had just come down from the mountains of Baguio, where I had been working on an epidemic of some sort, and felt that the weeks in high altitudes had so fortified me that I would yield to nothing.

I arrived at nightfall and enjoyed an American-cooked supper and went to bed. The next morning I was as well as I ever was, and thought that I was not to be bowled over by any disease. I ate breakfast with the family, then repaired to the library to discuss the trouble with Mr. W., the proprietor.

There was one very unusual thing about the farm. The people had two cows of their own, and used real milk—not the canned kind we usually had to depend on in the Philippines. So I naturally made inquiries about the milk. But Mr. W. said that the trouble could not come from that source. Their children, two husky lads, practically lived on this milk and they had never had the choleric trouble; and it was furnished to a neighbor, Mr. K., who lived on a neighboring pineapple ranch, and he had never suffered. So it seemed that the milk was wholly innocent.

While I was talking things over with Mr. W. (it was about two hours after breakfast) I began to feel some unusual distress. I soon sought the bed, where I spent the next twelve hours on my back. Mountain air notwithstanding, I was in for a sharp attack of the real thing.

I felt no alarm, since everybody got over the affair. Nor did the small boys of the family feel any alarm. They had no end of amusement at my retchings, for they had had like entertainment before. It was no fun for me. We had a spelling book in my childhood which made a point of illustrating by selected sentences how words of the same sound might have different meanings; for example, "The belle guessed that the guest rang the bell," and so on. Another sentence read, "The poor wretch retched violently." That was the sentence which often came to my mind when I was undergoing crises like this one on the farm—a sentence which repeated itself, like the note of the fever bird in West Africa, over and over with every throb of the brain.

In a day or two I saddled up and returned to my locusts, no wiser as to the cause of the mysterious disease of the farm, but much more experienced as to its effects.

About that time some ugly rumors began to spread in the neighborhood. People said that the servants of the farm, angered

by the American invasion of their hereditary agricultural rights, were poisoning the visitors. This, it was alleged, could be easily done with some native poison stealthily slipped into the food.

So during another interval in the locust work, I decided to revisit the farm and test this theory. I took along my own food, determined to eat nothing of the local fare except viands safely protected by tin containers.

I spent several days on the farm without a symptom, breathing the air, drinking water from the well, being only careful to avoid food which might be poisoned. I spent one night with the neighbor, Mr. K., and learned nothing there except that whatever the cause of the mysterious illness it was not bedbugs—I would surely have suffered an attack if their bites had been the cause of it.

Finally, it came time to go back to the locusts and I did not seem to be nearer the solution than I was when I had come. So I quit the tinned foods, ate breakfast with the family, saddled up my horse, and started on the trip back. When I had not traveled much more than halfway, on came the same old symptoms. By this time they were familiar to me, but it was a new experience for the horse. He had probably never had a rider who insisted on such frequent interruptions of the journey. On my reaching the home town, I took to my bed again for a day or so.

But this time I brought back with me at least a working theory. As on the morning of my first visit, I had partaken at breakfast of that characteristic American dish, breakfast food and cream, and the cream had come from the farm cows. The trouble must have been the cows, in spite of the exonerating evidence. I then had to return to Manila, but we asked that a sample of the farm milk be sent to us. It came packed in ice and was refrigerated the night after its arrival. I measured out a dose of cream and swallowed it down; I knew it would not kill me at worst.

Nothing happened, not even a touch of the illness! So could it be the cream after all? I tried a second dose, this time after the cream had stood at room temperature for some hours. Then on came the familiar misery. Now I had found something; the poison was bred in the cream, but was formed only after it had

been at room temperature awhile. I remembered that the W. family had no refrigerator; they kept their milk and cream in the cellar or springhouse, as all American farmers did before the epoch of ice and refrigeration.

Now it became of importance to know which of the two cows was responsible; particularly so, because one of the animals, the senior cow, had once suffered an attack of garget, an infection of the udder. By that time I was temporarily tired of being the guinea pig of this research; I tried animals but they did not seem to respond. I gave one dose to a monkey, a household pet, who trustfully ate the cream with gusto. He had not a symptom that I could be sure of except that he lay flat on his stomach a minute or two. Jocko was such an unprincipaled beast that he was not above pretending an ache just to deceive me.

So I decided to try a couple of Filipino laboratory boys. I explained just how little danger there was: I myself had survived three attacks, and would they be willing to help? They were promised a reward, of course, for their contribution to science. Oh, yes, they were very willing. So Venancio took a dose of the young cow's cream; Cirioco, of the old. And they relished it mightily; maybe it was the first real cream they had tasted in their lives. All went well with Venancio, but in a couple of hours or so came a cry of distress from an adjoining room, "Oh, Doctor, oh, Doctor," and poor Cirioco was laid up for a day or two—with a worse attack than any of mine, because Cirioco had not been fortified by a stay in mountain air.

So it was the old cow, the one which had had the garget.

Now what was in the milk of that cow which made her socially unpopular? I had to find that out, and so I made a bacterial culture of the cream. Behold! in that from one quarter of her udder appeared a great swarm of colonies of white staphylococcus, a bacterium very unusual in normal cream. The next step, of course, was to determine if this particular staphylococcus was guilty. I got some milk above reproach, a sample of tinned milk from Norway, and inoculated a quantity of it with a pure culture of the white staphylococcus. There was no taking chances with monkeys

or laboratory boys this time; I measured out a dose and swallowed it myself. Here was a dose containing only the staphylococcus and Norway sterilized cream. What would it do? The result could be recorded as distinctly positive, for I had the worst attack of all, even a touch of cramps with it. So the perennial sickness at the farm was due to staphylococcus carried by an old cow with a history of garget.

As in all detective stories, one has to have a chapter explaining how. The family did not use much cream; possibly they saved it for the visitors who would certainly appreciate an American luxury—real cream. It was the milk, not the cream, which the merry juniors partook of; milk caused no trouble, for the bacteria required some hours at room temperature to produce the toxin. And Mr. K., on the pineapple plantation, used only a little milk for his coffee. (One can appreciate how refreshing a touch of milk was after a long, hard night with bedbugs!) And the reason why the disease afflicted visitors only at a certain time of the year can be easily explained. Of course, that was the season when the cow was "in"—that is, giving milk. But those alibis, the lads who "just lived on the milk" and K., of the pineapple farm, were the factors in the problem which diverted me from the real solution for so long a time. As Sherlock Holmes might say—but the reader can guess. "Cows, of course; they were the only unusual element in a very unusual occurrence. You should have solved the problem without leaving your first sick bed."

I inquired what eventually became of the cow, Cholera Mary, as we dubbed her. We got news of her after she had become the property of an institution (of all kinds!), an orphan asylum. But no harm came to the orphans. Probably Filipino orphans never got enough cream to endanger them.

And the locusts? The micrococcus, despite thirty virulence promotions, never spread in the wild swarms—fatal as it was to the caged ones in the laboratory. Possibly the French savant who reported success with African locusts would also have fared poorly with the Filipino kind. But I have regretted that instead of *Micrococcus acridiorum* I had not dosed the locusts with my *Staphylo-*

coccus albus, which, I am sure, might have stopped their feeding for a day or two.

And this bit of research had not only solved the mystery of the isolated farm, but had added one thing to our knowledge of food poisons—that they may be formed by *Staphylococcus*. For ten or fifteen years nothing was heard of this type of food poisoning—maybe few persons read the *Philippine Journal of Science*, in which my experiments were described. Then after many years, news of the food poisoning by *Staphylococcus* came through Dr. E. O. Jordan of the University of Chicago, and my poor experiments were remembered. Nowadays such poisoning by either the white or the yellow staphylococcus is by no means unknown. And my laurels, if any, can be taken out of the attic, dusted, and worn, if ever there is any occasion for wearing them. And Venancio and Cirioco, with their pesos and cream, may not be the only ones rewarded.

CHAPTER FIVE: MALAYA AND THE FIJI ISLANDS

Again, as in the Philippine Islands, I visited a country primarily for the study of some other sort of microbe and finally "doubled" in malaria. The work in Malaya, undertaken during 1915-1917, had to do with the study of worms parasitic to man; but both of my colleagues, Drs. S. T. Darling and H. P. Hacker, were also interested in malaria, and we gave some time to malaria plasmodia which more properly, perhaps, should have been devoted to worms. However, the International Health Division of The Rockefeller Foundation, which employed us, did not seem to mind. Moreover, there was some good reason for the diversion, since the worms apparently caused much more damage to people who were also infected with malaria. And Dr. Malcolm Watson, now Sir Malcolm, was then resident in Malaya. Sir Malcolm, as all malariologists know, did fundamental work on malaria prevention in Malaya and is the author of a book on that subject.

Sir Malcolm, together with many other kind friends in the British Medical Service, soon made us feel at home with the various and picturesque peoples in Malaya and with the hardly less varied and abundant species of malaria-carrying anopheles there.

Our first acquaintance was with the famous *Anopheles maculatus*, so named because of the spotted wings of the adult mosquito. It is the chief malaria vector of the hilly interior part of Malaya, and, like *minimus* in the Philippines, breeds in bright, clear springs and streams. It is peculiar in its adaptation to very shallow, oozing water, so shallow that while the larva is feeding at the surface its underside almost touches the ground. This habit adds much to the difficulties of the sanitary engineers whose duty is to drain away the larva-breeding water, especially that in certain deep ravines common among the hills. It was not so difficult to confine the water at the bottom of the ravine in a narrow ditch, where, swiftly flowing, it bred few mosquitoes. But often the sides of the ravine were sloping and continuously wet with oozing

water, forming an excellent breeding place for the semi-amphibious *maculatus*. The difficulty was met in Malaya by supplementing the bottom drainage with tiling buried in the sides of the ravine, so that the "weeping" areas were dried up and made uninhabitable for mosquito larvae.

But the troubles of the engineers were not yet over. Certain water snakes found these underground drains very suitable for their dwellings, crept into them, and speedily clogged them up. These intruders had to be evicted from their new homes.

Another characteristic which *maculatus* shares with *minimus* is its fondness for sunlight. Malaria was once lacking in certain dark jungles of Malaya, but when the land was cleared and the rubber plantations started, it became rife. It was in Malaya that the idea was born of "jungle-izing" *maculatus*-producing streams in order to "shade out" the larvae; an idea which has spread to other countries, notably the *minimus*-infested tea gardens of Assam. Success seems to depend much on the sort of plant to be employed for the shading. The requirements are not always simple: the plant must grow well in the malarious fields; it must produce abundant shade; it must not be too succulent, else the cows will eat it; and, finally, it must not be too thorny or it will infest the bare feet of the tea-picking coolies.

Sometimes the interdependency of factors in nature forms a chain of widely differing links; as, for instance, one may associate war, synthetic rubber, and malaria. Should plantations be discontinued because the stress of war has forced us to make rubber synthetically, rubber plantations may be abandoned and become "jungle-ized," and thus malaria-carrying mosquitoes may be shaded out.

The hilly rubber-growing region of Malaya is infested with *maculatus;* but this species does not flourish in the stagnant, fresh-water pools and ditches of the plains near the coast. There it is replaced by *Anopheles umbrosus*, which, as its name implies, can breed very well in the shade, thus well supplementing *maculatus* as the woodland vector. Then there are numerous pools near the sea where the water is too brackish for either *maculatus* or

umbrosus. Here *Anopheles sundiacus*, the species we used to call *Anopheles ludlowii*, may flourish. It is a very efficient vector in the poorly drained waters near the coast, a type of water which may have vastly increased since the outbreak of our war with Japan. When the devil sowed malaria in Malaya, he took care to supply it with plentiful and efficient vectors.

The abundant rice fields of Malaya, like those of the Philippines, breed myriads of anopheles but fortunately scarcely any of the dangerous carriers of malaria. A common one is *Anopheles subpictus*, which I described in the chapter on the Philippine Islands, a rice-field breeder which commonly does not transmit malaria because it does not seek human blood.

It was important to know if this very common species could under any circumstances become a vector of malaria, a problem we attempted to solve in Malaya. First we had to determine if *subpictus* could be made to bite a human being and if then it became infected with malaria. Fortunately, we had in the hospital of Kuala Lumpur a Chinese who was an excellent carrier of gametocytes (the mature cells of the parasite ready to produce the male and female gametes). He came into the hospital one day complaining of some minor ailment; he developed a little fever, and so I examined his blood for malaria. To my surprise, his blood contained the gametocytes of *falciparum* in greater numbers than I have ever seen them in any patient—far more than one for every white corpuscle in his blood. We induced him to take up his residence in the hospital; he was too good a carrier to lose.

We coaxed the *subpictus* to bite him, using a dark cage placed next to his skin. The mosquito became abundantly infected, and the parasites developed normally. The next step was to determine if this *subpictus*-bred malaria was infective to human beings, despite the unwonted host. So we hired two other Chinese to serve as guinea pigs and applied the infected *subpictus* to their skins. In due time, they experienced typical malaria attacks, which promptly yielded to quinine. I am sure that one of them fully re-

covered, for he soon showed energy enough to steal the malaria money we had given to the other volunteer.

So we had shown that *subpictus* was susceptible to human malaria; and that it was such a poor carrier in nature probably because of its disinclination to bite man.

We rarely had any need for making mosquitoes transmit malaria to man, but we often had to seek volunteers willing to transmit malaria to mosquitoes. When we found a good gametocyte carrier, we often used him for all he was worth, one might say for all we were worth; for we usually paid a shilling or two per biting. One Hindu, who had proved to be an exceptionally good carrier, objected one day because I put seven cagefuls on him at one time—I suppose he wanted to be paid by the piece, not by the hour.

We employed many Chinese as assistants in field and laboratory and found them very apt at learning to identify mosquitoes, although they had had no previous training in such work. I had explained to my "boy" the difference between the mature anopheline mosquitoes and the non-anopheline, which we commonly called culicines. In the female anopheline the palpi, the long slender organs extending out from the head alongside of the proboscis, or bloodsucking instrument, are nearly as long as the proboscis itself; while in the culicines they are very short and stumpy. The boy's collections were properly identified, until one day he brought me a specimen which he could not make out. It proved to be *Anopheles brevipalpis*, a rare species which, although anopheline, has only half-length palpi. No wonder the boy was puzzled!

But one expects to find queer things in Malaya, where there is a fish which travels overland and where one uses the sea to get rid of water. We saw this ingenious form of drainage at Port Swettenham, a seaport where we spent some weeks studying worms and malaria. The engineers built dykes ("bunds," they called them) on the seaward side of the tracts of land which they wished to drain. These dykes were provided with gates which attendants opened at low tide in order to allow an outflow from the drainage ditches. Then they were closed at the approach of high tide to

keep the sea water from running back in. Thus land was reclaimed, and large areas were rendered uninhabitable for *sundiacus* and other mosquito species which love water part salt and part fresh.

Before I leave the subject of Malaya, I shall describe the jungles there. We read much of tropical jungles in the works of explorers and writers of fiction and, during the war with Japan, we heard much of the trials of soldiers in the jungles of Asia and in the islands of the Pacific. The jungles we usually saw in Malaya were rarely anything extraordinary, but often simply woods; sometimes the walking in them was as good as in a New England forest. There were some stretches hard to penetrate, boggy or full of vines and brush, but not much worse than many places I have found in the stream-side woods of the United States. Sometimes mountainside jungles were traversed by torrents which left rude boulder-strewn pathways through the forest, roads useful to the searcher for malaria mosquitoes, for he found passageway, and the streams contained many odd collections of water to dip for larvae.

The real jungles were hardly so interesting as those we had pictured in our minds before visiting the tropics. We did not find many of the masses of vegetation sometimes described as "vividly green except where blazing with orchids." It was mostly plain green, and to get much color one had to seek out a native house, where the color-loving people often planted hibiscus or croton, which helped to break the monotonous green of the landscape. Some wooded mountainsides in Malaya were more colorful. There the leaves were often tinted brown or purplish, and the woods reminded one of great billows of smoke rolling up the slopes—a scene of beauty I shall never forget.

The wild jungle animals, too, were not what I had been led to expect. The "tiger-haunted jungles" of Malaya never had enough tigers in them to do thorough haunting. Snakes were particularly disappointing. During many thousands of jungle hours in the tropical woods of the Old World and the New I have never encountered one poisonous snake. This was not because I was lacking in observation, for I had no trouble in seeing rattle-

snakes, which were plentiful enough on the prairies of Kansas in my youth. When I had to cross a snaky place barefoot, I used to run at top speed so that if I should tread on a snake he would not have time to coil and strike. And the cypress ponds of Alabama and Mississippi were full of the lethargic water moccasins, which were desirous of nothing except to be left alone with their prey—the fish. But in the tropics I saw hardly a venomous snake. Of course, the woods have a thousand eyes, and I presume I was seen by many snakes which I did not see. Perhaps that was the case in some cobra-infested places in India, where all I found was a chaplet of wadded cotton, an offering by the people to the snake deity, placed conveniently near some holes in the ground, presumably snake dens.

Very few of these wild things were hunting me except certain mosquitoes. When I wished to collect some of the rarer jungle species, the best way to find them was to let them hunt me—or us, for we often worked in pairs. One person took a comfortable seat and acted as bait; his companion, armed with a mosquito catcher, kept watch on the front, back, and sides of the bait, ready to pounce on the first specimen which bit—the earliest settler, one might say.

Poisonous spiders are particularly rare, and poisonous lizards unknown except in America. Of course there are sundry minor pests. In the Philippine mountains we used to encounter a sort of leech which lives on the leaves of trees in damp forests; we thought that these pests were on the lookout for us and were sitting on a leaf or twig in readiness to pounce. I have occasionally been bitten by them, but they never did me much harm. Sometimes they cause troublesome sores; especially, people said, when they are carelessly pulled away from the skin; the proper technique is to touch the leech with the lighted end of a cigarette, when he lets go harmlessly—in the Philippines one never considers the cigarette harmful! Sometimes they got into people's eyes, a particularly troublesome place for them; but this happened very rarely. Of course one often met with water-inhabiting leeches, more common in temperate than in tropical waters. I used to

wade a good deal without boots and had to guard against these pests, which were unpleasantly skillful in finding openings in one's leggings or stockings; but I found stockings of wool an effectual barrier so long as they had no holes in them.

One had also to reckon with vegetable pests—nettles, thorns, and the like. In one mountain region in the Philippines we had a trailing vine—a sort of palm—with back-turning thorns, which caught at the clothing—"Wait a bit" it is appropriately named. Once in coming out of the woods I had to stop at the dwelling of a perfect stranger and borrow a shirt in order to get something I could wear on my back on the way home.

Swamp "miasmas" never troubled in the jungles. Dangerous "miasmas" are to be sought in the villages where infected mosquitoes usually are most plentiful; a jungle is rarely "fever-laden" unless fever-carrying people live in it.

"Howling wildernesses" were present in the most literal sense in Malaya. The howling was done by a kind of large monkey, black and bob-tailed, which had a habit of hooting down the gamut as if practicing scales. The sound was a pleasant one to me, and I presume the monkeys enjoyed it too.

On the whole, I found far more joys than dangers in the tropical woods. Annoyances there were, but hardly more common than in the woods at home, and the Malayan "jungles" were if anything less jungly than those of other tropical countries I have visited.

In Malaya I had the luck to find malaria sporozoites in wild mosquitoes belonging to two of the malaria vectors there.

To readers who may not be familiar with sporozoites and the details of the manner by which mosquitoes carry malaria to human beings, a short explanation may be helpful. Before she can carry malaria to man, the female mosquito must be infected by a human being. When the mosquito bites a person with malaria, the parasites are drawn into the insect stomach together with the human blood. If these parasites do not include some individuals sexually mature, the gametes, the mosquito is not infected and remains harmless. But if mature male and female parasites are in-

gested, the male fertilizes the female, which then creeps through the wall of the mosquito stomach, takes a position on the outside of it, and there becomes a rounded body known as the oöcyst. After a period of time, usually ten or fifteen days, the contents of the oöcyst—or the greater portion—are transformed into tiny, elongated structures known as the sporozoites. These ripen and by the bursting of the oöcyst are set free into the body cavity of the mosquito. There may be many oöcysts formed on the stomach wall of one mosquito and each oöcyst may contain scores of sporozoites. These, when set free, migrate into various parts of the mosquito body but eventually most of them collect in the salivary glands of the insect—small organs situated near the insertion of the neck. When the mosquito bites a second human being, some of these sporozoites are injected into the human body. There they form new parasites, which within a few days multiply sufficiently to cause a fever, and eventually many of them mature and become new male and female parasites.

So here are the two cycles, the insect and the human. And the mosquito is harmless until it catches malaria from man, and normally one person cannot transmit the disease to another without a mosquito to carry it. Thus malaria is a disease of the mosquito as well as of man, although mosquitoes do not seem to suffer much from it; anyhow, they may carry hundreds of malaria oöcysts, enough to cover the greater part of the stomach wall, and still live and fly about. I have seen in West Africa as many as four hundred oöcysts on a single mosquito stomach, all nearly ripe and fully formed; and undoubtedly when oöcysts in such large numbers infest the insect, it may at least be inconvenienced by them. If we can imagine mosquitoes in convention, we may suppose one of their first resolutions would be to warn against all those plaguy human beings likely to give one an attack of malaria!

The chance of encountering a malaria-carrying mosquito in nature is, in most countries, rather small. Only anopheles transmit human malaria, and not all species are sufficiently malaria-susceptible or fond of human blood to make a good vector. After biting a gametocyte carrier they must survive ten or fifteen days

until sporozoites develop. Thus the sporozoite-carrying individuals are so few in most countries that we regard the finding of one as quite an event; especially because, if we were doubtful before, we now know that this mosquito species is definitely a dangerous vector.

Sir Malcolm Watson guided me to my luck in both cases; in one, he told me of a certain plantation hospital where patients sometimes entered with dysentery and departed with malaria; and it was suspected that infected *umbrosus* mosquitoes were infesting the building. The owners were about to screen the doors and windows to keep the mosquitoes out, and Sir Malcolm suggested that it would be a good time to examine some of them. I reached the hospital about the same time as did Sir Malcolm, who was accompanied by some friends to whom he wished to show the salivary glands of a mosquito. I dissected one for him, and by way of further demonstration, dissected a second one. There were the sporozoites in large numbers—perhaps the first time, or one of the very few times, they had ever been found in nature in that species. There had been some controversy as to whether *Anopheles umbrosus* was really a carrier of malaria; so that both Sir Malcolm and I were much pleased with the finding.

My second bit of luck came when Dr. Watson told me of an outbreak of malaria near some brackish water, where I might find some *Anopheles sundiacus* for dissection. I sent my Chinese boy this time, and he returned regretfully carrying the only specimens of *sundiacus* he could find, about four or five. One of these had beautiful oöcysts, which were not so novel, but also abundant sporozoites, which were rare enough at that time in *sundiacus*.

I have spoken little about the people of Malaya, the most interesting feature of the peninsula. So great was their variety and picturesqueness, and that of their vehicles and beasts of burden, that I used to think a mile of the usual traffic along a highway would do for a circus procession in America; nobody would go home disappointed. At the time of our visit there were four predominant races, each with different occupations, religion, and habits. There were the white Christians, the brown Malays, the

yellow Chinese, and the black Hindus. One is reminded of the story of the fisherman in the Arabian Nights who caught fish of four colors, each kind a people transformed by evil enchantment. The Malay States, at that time one of the richest parts of the British Empire, abounded in tin mines and rubber plantations and offered a suitable occupation to each of these races. The white Europeans were then the rulers of the country; the Malays, the original inhabitants, were the local rulers, and engaged in agriculture and commerce; the Chinese had been long established as merchants and tin miners; and the Hindus, mostly Tamils, were principally workers on the rubber plantations. All suffered from malaria more or less, much depending on how well they protected themselves and how tolerant they had become of the disease in their youth. The Chinese apparently suffered least, possibly because of their custom of sleeping under bed nets—a custom almost universal among all classes of Chinese; I have seen rude cloth nets even in the huts of poor fishermen. Most native people of the poorer classes are content with wrapping up in a blanket or other covering as a protection against mosquito bites.

I have coupled Malays and the Fiji Islands in one chapter, because we visited both at about the same time and for the same purpose—the study of parasitic worms. In Malaya the people were infested with both worms and malaria, while the Fijians had worms in plenty but no malaria. Our study had to do largely with the effect of parasitic worms on health; thus in the Fijis our problem could be simplified by the elimination of one unknown quantity—malaria. So on leaving Malaya, we turned southward, traveling by way of Java, New Guinea, Australia, and New Zealand, and arrived at Suva, the capital of the Fijis, about the first of July, 1917.

The traveler could hardly find in the habitable world two localities offering greater contrast in land and people than Malaya and the Fijis. One is a tropical, woodsy peninsula; the other a high, wind-blown Pacific island group well below the equator. One land is rich in tin and rubber, the other in palms and gold. The native Malays are small, almost feminine in limb and stature,

while the Fijian is tall and broad-shouldered, with erect head and with the frizzled hair characteristic of the Papuan race of Oceanics.

The reason for the lack of malaria in the Fijis is the absence of anopheline vectors; there are indeed plenty of mosquitoes, but no anopheles and no transmission of malaria. I examined some very promising pools for anopheles early in our stay, and had no more luck in finding them than did previous searchers. Truly, there was some introduced malaria in the islands; the anopheles, if any had been there, could have found parasites to infect them. I remember particularly a Solomon Islander who came into the Suva hospital for shark bite—the only case I had ever seen of this accident. (Sharks, like poisonous snakes, are bad enough, but their reputations are worse than their bites.) This Solomon Islander had abundant malaria parasites in his blood.

A very curious thing, the distribution of anopheles in the South Seas. As we know from the recent experiences of our troops, there is abundant indigenous malaria in the New Hebrides, the Solomons, and westward through the whole of the East Indies. But there is none eastward among the Pacific Islands up to the South American coast. Even on the island of Juan Fernandez, the castaway who was the original of Robinson Crusoe could not have counted malaria among his woes. The lack of anopheles on those islands may be due to their inability to get that far east over the wide stretches of ocean separating the island groups—too wide for mosquito flight, and not sufficiently traversed by man or animals which might transport the insects.

One wonders why mosquitoes are not more often carried by migratory fowl. Ponds and swamps frequented by wildfowl often harbor the larvae and eggs of mosquitoes. It would seem that, in the course of centuries, mosquitoes might be widely spread by wildfowl migration, and would come to frequent all places where they are able to breed. Eggs of anopheles do not well resist drying, and this disability may help account for their lack of universal distribution; but eggs of many other mosquitoes, the carrier of yellow fever, for example, are much more hardy. They are able

to survive on dry land for many months, and one would expect them to be carried everywhere. Possibly wildfowl do not range widely in the Pacific; or they may be particularly neat about the condition of their feet or feathers and do not tolerate sufficient mud or scum to harbor mosquito eggs. In airplanes, conditions are much more suitable for the survival of mosquitoes, certainly of the adults. In some parts of the world, malaria mosquitoes have already made long journeys far from their native habitat in ships of the water or of the air, and it may be that anopheles have already immigrated to Pacific islands where they were not known in 1917, when we visited the Fijis.

We found the Fijians a strong, upstanding people in spite of their worms, so that on the face of this evidence, one would conclude that worms are definitely the lesser evil; but I doubt if the Fijians themselves would ascribe their superior stature and robustness to the absence of malaria. They think that their physical superiority is due to the fact that they do not have too many children; births are so well spaced that each child has years of maternal care before being crowded out by the oncoming brother or sister. But this custom, apparently so hygienic, may be the undoing of this people; for the more prolific East Indian immigrants threaten to crowd the Fijians out.

Certainly a casual examination of the principal island, Viti Levu, where we did our work, would indicate a healthful land, mountainous and directly in the path of the ocean winds. As pointed out by Dr. S. M. Lambert, author of *A Yankee Doctor in Paradise*, the greatest menace to the health of these Pacific islanders is their visitors and the diseases of civilization which they bring to peoples unaccustomed to them. In the case of one disease, measles, it happens that the disease was brought in not by foreigners but by one of the Fijians themselves—a chief, as I remember, who contracted it while on a visit to New Zealand. Measles was new to the islanders and a large percentage of them died of it, because they were lacking in resistance to the disease, a protection which we of the continents have acquired by centuries of experience with it. From accounts I have read of this

epidemic, the people were also lacking in a knowledge of how to treat the disease: exposure of the patient to rain was employed as a remedy for a high fever. Malaria may well be a more serious menace to the Fijis than measles, for it is the more dangerous disease and likewise would find a highly susceptible population awaiting it.

As might be expected, the Fijians were not very susceptible to parasitic worms, which their ancestors had probably harbored for centuries. I examined a considerable number of blood specimens of the people of a village far in the interior of Viti Levu. I found not one person malaria positive, but a considerable percentage—over one-third—infested with filaria, a microscopic, blood-inhabiting worm carried by a mosquito not of the malaria kind. This worm is the cause of a huge enlargement of the limbs and other members of the body—a disease known as elephantiasis; but none of the Fijians of this village were afflicted with this disease, in spite of the large percentage infected by the worm.

On this trip we spent the night in a Fijian dwelling—a very comfortable lodging. The floor was strewn with soft herbage covered by mats, which made a very acceptable bed, and an enclosure on the floor was fire-proofed for cooking. The ceiling was high and pointed, and the doorposts made of the trunks of the tree fern, a wood famous for its strength and durability.

On our return from the inland village, we traveled part of the way by horse and part by boat, shooting rapidly down a river in a very swift current. I was reminded of a voyage down the Neosho River in Kansas during my high-school period; where, as in the Fijian river, the swift current would suddenly dive under a steep bank, requiring some skill on the part of us prairie sailors to avoid an upset. I think the Fijians were better steersmen than we. During this voyage, we had the rather novel experience of finding ripe bananas on the tree. Viti Levu exports many bananas to Australia and New Zealand, but, as almost everywhere, the fruit is picked green and ripened after arrival at its destination.

The coast of this island is most attractive, surrounded as it is by a great coral reef running parallel to the island shore, far

enough out to afford a wide and calm passage for island steamers between land and reef. In front of the larger harbors, the ship might find a natural opening in the reef wide enough for an easy exit to the open ocean. This passage is usually formed near the mouth of a river, the outflowing fresh water of which checks the growth of the coral organism forming the reef, thus accounting for the convenient opening.

During violent storms, high waves break on the encircling reef and throw up a misty spray, which, at a distance, suggests the white smoke of a prairie fire on the plains.

The great reef offers a dwelling place for all manner of fish and other sea life; and, as might be expected among a sea-going people, it harbors many salty legends. One of these had to do with the turtle god, who was unfortunate enough to fall into the trap of a fisherman. To secure his liberty, the god gave this fisherman the peculiar power of walking barefoot and unharmed over hot stones lining the pits where the people's banquets were prepared. The fisherman and his descendants have ever since enjoyed this fire-walking privilege. Eyewitnesses have told us that they could vouch for the wonderful feats of these human salamanders.

It may have been through their fire-walking ancestry that some persons lay claim to a sort of aristocracy. We had as our assistants in the parasitic worm work, two princes of the blood, who came to us from a neighboring island famous for fire walking.

Suva was certainly modern at the time of our visit in 1917. Two of the most striking buildings which one sees as he approaches the harbor are a large modern hotel and a great Carnegie library, said to house an extensive collection of books on the Pacific islands.

The majority of the people are Protestants, many of them Methodists. In the old days before the missionaries came, these islands had a reputation for cannibalism. Sailors shipwrecked on the islands were particularly likely to be eaten—people "with salt in their eyes" were fair game. But cannibalism has long been unknown; we were told that only one man with cannibal experience

remained on the islands at the time of our visit. He is said to have observed that the flesh of white men is not good—too much flavor of salt and tobacco.

Our visit occurred during World War I, but there were then only faint echoes of war in the Pacific. On the voyage between the Fijis and Hawaiian Islands, we kept the windows blinded so as to afford no guiding light to a certain German raider supposed to be then prowling in that part of the ocean. But this raider, it proved, had long since piled up on some Pacific beach and prowled no more.

CHAPTER SIX: EQUATORIAL AFRICA

My next journey was perhaps the most memorable of all, a visit to the Arsenal of Malaria, Equatorial Africa. I was again associated with workers in another disease, with the Yellow Fever Commission of the International Health Division of The Rockefeller Foundation, which made noteworthy discoveries in yellow fever in West Africa. We lived in the Yellow Fever Compound, a group of buildings situated at the native village of Yaba, a few miles from the city of Lagos, Nigeria.

Most of our anti-malaria work was done in that part of West Africa lying below the Sahara Desert. In this region, lying within the equatorial belt, we find conditions greatly favoring a high incidence of malaria—a warm climate and abundant rainfall, which favor the production of anopheles, and numerous human inhabitants who enjoy neither protection against mosquito bites nor adequate treatment for the disease. In speaking of Africa as an "arsenal of malaria," we imply that it is the source of the disease for other countries. I have mentioned the slave trade as a probable factor in carrying malaria from Africa to the Americas—at least many strains if not species of the parasite. This trade supplied slaves to English, French, and Spanish colonies spread over a large part of the New World; to New England, Brazil, and much of the territory lying between them. The slave trade was known long before the discovery of America, and was continued to Europe long afterwards. Arab traders were notable dealers in slaves, for the Muslim religion permitted the enslavement of any Negro tribe not converted to Mohammedanism. One of the chief aims of David Livingstone, famous missionary and explorer, was to break up the infamous African slave trade. It is highly probable that slaves brought in from the malarious parts of Africa were the source of much of the malaria which gained a hold in countries around the Mediterranean basin. Just as in the Americas, the parasites undoubtedly found an abundance of mosquito vectors ready on the ground.

One is tempted to look to Africa as the place of origin of human malaria; but all questions as to the origin of this disease are, of course, matters of pure speculation. However, we have some facts which may be pertinent as to the how and where of the first human malaria. There are many species of the disease among birds and the lower mammals, species ordinarily never transmitted to man. Several occur among monkeys, and one of these may be transmitted to man artificially, although it is unlikely that such transfer commonly takes place in nature; but it is thinkable that such monkey malaria may, in the course of centuries, have become adapted to some cousinly race of man. Africa exhibits a very great variety of races of both man and malaria, and it is possible that there some monkey strain found its first bridgehead to man.

We have evidence that the Negroes of Africa have some racial tolerance of malaria, an indication of a long association with the disease. I have mentioned the tolerance of the effects of parasites which people acquire by association with malaria from childhood, and I believe that Negroes acquire this tolerance more easily and more completely than do other races. We also have some more tangible evidence of a racial immunity among Negroes, for enlargement of the spleen, a characteristic of chronic malaria, appears to be less marked in this race. We have made some comparisons of splenomegaly among people native to Nigeria and those of Greek Macedonia, which indicate that marked spleen enlargement is less common among Negroes. Marked splenomegaly is comparatively infrequent among malaria-infested Negroes in the United States.

In another line of evidence the facts are better known and perhaps give us a surer ground. We find in Africa a species of anopheline mosquito, *Anopheles gambiae*, which exhibits evidence of a long association with man; indeed, it is almost a parasite of man, preferring his blood to that of any other mammal. The larva is often found in waters more or less domestic; the adult commonly frequents human dwellings, where it tolerates the smoke of cooking fires remarkably well. It is very susceptible to malaria and is responsible for much of the malaria found among the

Negroes in Africa. This close association of vector and host may indicate that malaria has long existed in Africa; it does not prove, of course, that it originated there.

At the time of our visit in West Africa, 1929 and 1930, the amount of endemic malaria there was appalling. The parasite, as was shown by our surveys and those of other investigators, is almost universally present in the blood of native Africans. The British medical authorities of Nigeria required vaccination against smallpox for infants three or four months old, and we availed ourselves of the opportunity of getting blood specimens from them. Among infants, four months old or less, brought up for vaccination in Ebute Metta, a city situated near Yaba, we found forty-five percent with malaria parasites in their veins. A blood parasite survey, however carefully done, will fail to detect some cases of malaria—a tiny drop of blood is such a small sample to search; so that one may safely assume that, by the fourth month of life, fully half of the native population is infected with malaria. Examination of blood samples of older children indicated that none escapes infection by the end of the first or second year of life. I examined personally blood specimens of several thousand native Africans of Nigeria, ranging in age from one month to sixteen years or over, and found over sixty percent positive—an indication of the enormous amount of malaria in the population.

Parasites are usually most numerous in the blood of persons undergoing their first attacks; for example, in people newly arrived in a malarious region. African infants are truly such newcomers, and in their blood we often found parasites in vast quantities. With large numbers usually goes a larger percentage of sexually mature parasites, those capable of infecting mosquitoes. We found very many of such "gametocyte carriers" among African children, and since these are unprotected from bites, we should expect a high index of infection among the vector mosquitoes of that region. Such, indeed, was the case in the chief vector, *Anopheles gambiae*, in which we found over six percent sporozoite-infected in a lot of many thousands of mosquitoes we dissected. This percentage was higher, up to ten or more in many localities,

during certain seasons. When we think of ten percent malaria-carrying in a numerous and highly domestic species of mosquito, very voracious and confining its attacks almost entirely to man, we get some idea of the malaria danger in that locality. We read accounts of fatal attacks among white people of "coast fever" following a nocturnal stay of only a few hours in a native village. Such accounts seem credible when we consider the high percentage of mosquitoes which are sporozoite-carrying. We used to say that if one were particularly lucky, he might escape with nine "free" bites to one infecting bite! And we wonder that a single native infant escapes infection for four weeks or even four days of life. Possibly these very young infants enjoy some immunity carried over from their mothers; of this we lack positive proof, but such immunity is acquired with some diseases and may serve to delay malaria infection among African infants, almost all of whom are born of mothers who have survived many attacks of the disease.

One would expect to find everybody ill all the time in a population so highly infested with the parasites of a disease like malaria, but such is by no means the case. Among children, there are much sickness and many deaths; but it is often difficult to tell how much of the illness is the result of malaria and how much of some other disease, particularly dysentery. One finds an infant feverish and quite ill; its blood may be literally swarming with malaria parasites. But if one examines its brother or sister, living in the same house and apparently well, one may also find numerous parasites.

Naturally wanting to know what became of infants thus heavily infected with malaria, we followed the history of some such infants through several months. It was not easy to follow many of them, because the native African changes his place of residence frequently and is not always easily found; but it appeared that the majority of these infants survived. So we are inclined to suspect the presence of some native immunity to malaria. We found two cases of white children untreated and harboring malaria parasites who also survived, but we could not conclude much

from this small number. Untreated white children were rare in West Africa; the parents of these two were missionaries belonging to a peculiar sect which forbade the treatment of the sick. Two adults of this family—mothers—had died and the father and both children were malaria-infected; so I presume the father had always been loyal to his faith. As I shall describe in the chapter on malaria in Brazil, one finds a terrible mortality among both children and adults in a population newly assailed by epidemic malaria and possessing no resistance to the effects of parasites. Possibly, then, the African infant is the better able to survive because he draws in some immunity with his mother's milk.

We made many visits to one African infant named "Taiwo," which is a sort of generic name given by some tribes to one of a pair of twins. Taiwo's blood was particularly rich in parasites, and we needed to apply mosquitoes to him many times. We always paid a shilling and a quantity of quinine for each biting, so that our visits were welcomed by the parents. Indeed, it happened that the father had lost his employment through some misadventure, and Taiwo was for a time actually supporting the family with his blood!

Taiwo himself hardly noticed the bites, for by that time we had devised a superior technique for mosquito bitings. In the Lagos market one could buy a dried "juju" gourd, a long cylindrical fruit about five inches in diameter, hollow and covered with cabalistic designs, the work of the juju priests. This we sawed into rings, each about an inch deep; we then covered a ring at either end with mosquito netting, thus forming a sort of small, flat mosquito cage. Many cages could be made from one gourd, which cost only a shilling including the charms; these, I fear, did not survive the process of cage-making.

The mosquitoes were introduced within this cage, which was then thrust under the patient's shirt, where it found a warm, dark, moist environment next to the skin. There the mosquitoes usually bit very promptly; I have often used these cages on my own skin to feed non-infected mosquitoes because they bite so well

in them. Since anopheline bites are comparatively painless, Taiwo scarcely noticed them.

Among native adults in Nigeria, we find some definite cases of malarial sickness, but they are remarkably few considering the vast number of people continually harboring parasites in their veins. We occasionally found cases among the adult African employees of the Yellow Fever Compound at Yaba. The illness was relatively very mild, with a little fever, a soreness in the spleen, and an increase in the number of parasites in the blood. These findings are interesting in that they show how hardly won is complete resistance to the effects of malaria parasites; for these people had been infected from babyhood, and had received uncounted doses of malaria sporozoites in their blood; but they still had occasional symptoms of the disease.

I have spoken of *Anopheles gambiae* as the commonest mosquito in the native houses of Nigeria. The breeding habits of its larvae, like the resting habits of the adult, are very domestic. One often finds larvae in city streets, often in pools contaminated by dead animals or human excreta. Ponds commonly used by the people for laundry or bathing purposes are often heavily populated with the larvae of this species, and watering pools frequented by domestic animals are also favored breeding places. These larvae were not fond of certain jungle streams, shaded and containing water of a brownish color, resembling that of weak coffee, nor were they plentiful in certain large ponds full of aquatic plants; an important matter, as we shall see when we consider the invasion of Brazil by this species. We searched for these larvae in the jars and pots used for storing water in houses, but never found any there. In a country less rainy than Nigeria, these containers may become dangerous breeding places for *Anopheles gambiae*, for mosquitoes may be forced by drought to less accustomed breeding places.

This species, like *Anopheles albimanus* in Central America, breeds well in rain pools, a habit which makes them particularly troublesome; for any depression in the ground, even those only two or three inches deep, may hold rain water and harbor the

larvae of *gambiae*. During the height of the rainy season rain pools may spread over huge areas. I have found larvae particularly abundant near the houses of villages inundated by the rains.

Close to our house in Yaba, there was a large pasture crossed by the trails of cattle driven from the north to supply meat to our neighborhood. Nigeria is infested by the tsetse fly, vector of a cattle disease which restricts the production of cattle to certain native breeds insufficient for the beef requirements of the country; so cattle had to be imported for slaughter, many of them a humped, big-horned breed from upper Nigeria.

I made frequent observations of the rain pools formed in these cattle trails, to determine how soon after the rains began they would become productive of malaria-carrying *gambiae*. I found that in hardly more than a week, eggs were deposited there and mature mosquitoes bred. Mature females of this species are ready to bite in less than a day after they emerge; and we have found sporozoites in the salivary glands, well formed and apparently ready to infect, nine days after the mosquito had bitten a gametocyte carrier; so that some more hardy mosquitoes might breed, get infected with malaria, and transmit it to a new victim within eighteen or nineteen days after the rains begin. This short period is probably confined to a very few individuals, and it is likely that an interval of several weeks would elapse between rains and a significant rise in malaria prevalence. In that part of Nigeria, *gambiae* finds many breeding places during both wet and dry seasons. The city of Lagos, for example, is surrounded by a wide lagoon, fresh during the rainy season and brackish during the dry, both sorts of water favorable for *gambiae*. But when the rains begin, whether the chief rainy season in June and July or the "little rains" of autumn, the production of *gambiae* rapidly increases.

At the village of Yaba, the average number of *gambiae* in the houses of the natives employed by the Yellow Fever Commission was not particularly large during the dry season—about four per room could be found resting in the dwellings during the daytime; but the percentage of females infected with sporozoites was

large, about twelve percent. One can imagine how carefully we had to remain behind screens at night. The mosquitoes had plenty of Negroes to bite, but they seemed anxious to get into our house. This was especially true during the period of greatest mosquito prevalence, which came soon after the beginning of the rainy season, when they would collect by the dozen on our screens, especially those under a vine-covered veranda at the front door. We had the mosquito collector bring some of these in for dissection, and we occasionally found malaria-infected specimens among them. So during the mosquito season, we made it a habit to enter by the back door, where fewer mosquito visitors were waiting to get in.

Malaria was not uncommon among the white inhabitants of Yaba. We thought that we contracted most of our attacks at garden parties or in unscreened houses in Lagos, where we were entertained by our English friends. Our own screens seemed to be efficient. I myself did not contract malaria in Yaba, although I did not take any "prophylactic" treatment regularly.

The malaria preventive commonly used in that region was a dosage of six grains of quinine daily; a bottle of tablets nearly always stood on the lunch table—a conspicuous reminder not to forget one's dose. This mild dosage usually served to "repress" malaria if taken faithfully during one's stay in the tropics and if continued on the way home to England. If the dosage was neglected on the voyage, one sometimes came down with the disease when the ship got into cooler latitudes. Some of our friends of long experience in Africa did not believe much in the "prophylaxis," and never bothered with quinine until they got malaria; then they took regular treatment.

The native people were not very sensitive to mosquito bites. My colleague, Dr. Theodore Hayne, used to bring the people together by means of out-of-door cinema exhibitions, not primarily to edify the audience, but to enable him to study mosquito biting. The people, absorbed by the movie, kept their eyes on the screen, unmindful of the bites, and allowed the investigators to pass among the seats, mosquito-catcher and cage in hand, and pick

the biting mosquitoes from the bodies of the audience. Thus night-biting could be studied—an important subject when one deals with transmitters of yellow fever; these, by the way, bite day and night, whereas malaria vectors rarely bite in the daytime. I daresay any film would do for this movie, provided it is sufficiently interesting to hold the audience. It occurs to me that an outdoor African audience might be useful for a preview of certain kinds of movie (just as it was once customary to exhibit a legitimate play to a college audience before taking it to New York). If the people never squirm, however severely bitten, the film might be considered a success and immediately transported to New York and exhibited there.

Many *gambiae* mosquitoes were bred in waters within a half mile of Yaba; one pool, a favorite native laundry and bathing resort, was full of larvae. Another pond served both *gambiae* and native devil-worshippers. We often found larvae there, and with them offerings, bundles of chicken feathers and the like, to the devils which supposedly frequented that shrine. We were never sure whether these charms were designed to attract devils or to keep us away; and I fear we were not sufficiently observant of native beliefs to care much. We were sure that the rites protected nobody from *gambiae*, so we spread larvicides in this pond as we did in the others of the neighborhood. Neither priest nor devil seemed to mind Paris green, but the larvae were effectively destroyed.

I have generally found natives rather tolerant of the doings of white people, especially of those engaged in health work. Perhaps they think that the foolish behavior of Europeans in studying microbes or larvae is not a matter for their serious consideration and that probably the devils or other deities are of the same opinion. And it is to be remembered that in West Africa many of the natives are Christian or Mohammedan and hold pagan beliefs in small regard.

In the interior of Nigeria, we visited Ibadan, a city of nearly a quarter of a million inhabitants, the largest in that part of Africa. In most malarious countries, large towns have relatively little ma-

laria; but Ibadan, like many other African towns, has a very high incidence of the disease. We found adult *Anopheles gambiae* about as numerous as at Yaba and their sporozoite index slightly higher, about thirteen percent; blood specimens of a hundred school children we examined showed over ninety-one percent malaria-positive. Yet there seemed to be no large amount of pool, swamp, or other mosquito-breeding water in the neighborhood. We made no extensive surveys, but it appeared that some small streams flowing through the town were the principal source of the anopheles. Ibadan would be a good place to try malaria control by an attack on the mosquito carriers—there are so few mosquitoes and so much malaria to control. Screening might be practical if one could get the native people to screen. The construction of the houses, some of which we visited, seemed to favor the comfort of the mosquito rather than that of man. Behind the main dwelling room is a large storeroom completely dark and windowless, where with a flashlight one could find adult mosquitoes, anopheles and *Aedes aegypti* (a vector of yellow fever), resting contentedly on the ceiling. Certainly this city is a paradise for disease, and it is chiefly the resistance of the people, inborn or acquired in childhood, which is their protection against extermination by malaria and yellow fever. I doubt if they get any more assistance from their native deities than do the people of Yaba. We visited one shrine inhabited by a sacred crocodile, which formerly, it is said, partook of human sacrifice.

Another city or large village of Nigeria is worthy of a short description, Otta Town, situated in a hilly region nearer the coast. There we found a blood parasite index among school children of ninety-three percent; but, as is generally the case in highly malaria-endemic localities in West Africa, few if any persons were ill with the disease. The anopheline mosquito population was very sparse, only one or two adults per room, but the sporozoite index was extraordinarily high, nearly thirty percent, the highest index ever found, among "wild" mosquitoes in any country, I believe, until N. C. Davis found its like in the great epidemic in Natal, Brazil. The extraordinary index of Otta Town was ob-

tained in the dissection of 202 specimens—the mosquito collections of ten months, representing the ordinary index, not that resulting from an epidemic as in Natal. When I began to dissect the anopheles of this locality, I suspected some error in the technique, so high was the percentage infected; but further dissections confirmed the earlier results.

The town is surrounded by a jungle in which there seems to be little production of *Anopheles gambiae;* a ditch in the town itself appeared to be the only breeding place, at least during the dry season. It may be that the very few specimens of *gambiae* found in the houses had been there a long time; the few we could find may have been the survivors of a much larger mosquito population. One can imagine what would happen to a malaria-susceptible visitor if he spent one or two nights in that village. Otta Town, like Ibadan, would be an excellent place to try control of malaria by the prevention of mosquito breeding, especially if it proved that the mosquito population is sparse during the wet season as well as the dry. It is probable that one would find coöperation among the people, at least few, if any, objections. The native ruler of that district of Nigeria was favorable to health work, and the local chief was very friendly to anyone who showed an interest in his remarkable collection of native hats.

In many West African localities, the prevention of malaria by larval control would not be easy. As an experiment, we tried to control anopheline production around Yaba by means of Paris green, after we had surveyed the breeding places around the village within a radius of about a mile. We had to spread this dust about every five days, for the development of *gambiae* in that tropical climate was very rapid. At the end of our "campaign" there were still adults coming into the village, apparently from brackish water situated over a mile away.

This work was done during the dry season when breeding places were few. After the rains came on, the larval control of this village would have been much more difficult. Happily there are now other anti-mosquito measures available, screens and adult-killing sprays, and a larvicide, DDT, much better than the one

we used; so that malaria prevention through anti-mosquito methods is by no means hopeless, even in Nigeria.

After our stay in Nigeria, we spent some months in Liberia, the Negro Republic of West Africa. This republic was founded by American Negroes manumitted about the time of the administration of President Monroe, the capital and chief seaport of the republic, Monrovia, being named in his honor. There are two main groups of people living in the country: the first, the descendants of the original founders and mostly dwelling in and near Monrovia, and a second, a much larger group, living in the interior of the country and consisting of native Africans. The first group is the ruling class, and the second is not only subject to the Monrovians, but, it is said, occasionally enslaved by them.

Economically, Liberia is less advanced than Nigeria, especially in respect to the food supply. Nigeria has an abundance of oil-producing palm and other tropical products, sources of wealth for home use and export; while Liberia depends much on upland rice as an article of food, at least in the interior of the country. The cultivation of upland rice brings no mosquito-breeding danger, for it is conducted in a manner far different from that observed in the rice paddies of most tropical rice-growing countries. A parcel of woodland is cleared of trees and brush, and most of the cut-away debris piled up and burned, a process which clears a large part of the ground and admits light. The tree roots and stumps are let alone, and the soft humus is seeded with rice without plowing. One or two crops are grown, and then the plot is abandoned; the forest is allowed to reconquer the land, and new parcels are prepared. No irrigation is needed for "dry" rice cultivation. This primitive agriculture is also employed in the Philippine Islands and other localities where woodland is abundant and food requirements are relatively small.

In Liberia we lived on the Firestone Rubber Plantation, the guests of Dr. and Mrs. J. B. Rice. Dr. Rice, then Medical Director of the plantation, furnished us laboratory room and coöperated in every way. Later, Dr. Rice worked with us in Greece, Egypt, and India—an invaluable colleague.

Our chief research on the Firestone plantation was a further test of plasmochin, the synthetic drug which I have described in the chapter on Central America. The reader may remember that we worked with it on a plantation of the United Fruit Company in Panama, and confirmed the discovery that this drug, given to the malaria patients in very small doses, has the power of killing the sexually mature parasites or at least of rendering them nonviable—that is, unable, when drawn into the stomach of the mosquito, to continue their development.

In Liberia we planned to give frequent nontoxic doses of this drug to large numbers of people, and to measure the result of the treatment by its effect on the sporozoite index of the anopheline mosquitoes, especially of *gambiae*, which infested the plantation. This experiment required a locality where a large proportion of the people could be treated and where there was enough malaria in the population to enable us to test the results.

The Firestone Rubber Plantation met both of these requirements. Laborers were plentiful; they lived on the plantation and were willing to take the drug, and there was certainly enough malaria there for measurement. We found a blood parasite index among the native people of nearly eighty percent, and a sporozoite index in *gambiae* of three and one-half percent—less than that of Nigeria, but sufficiently high for the experiment. Possibly the lower sporozoite index of that locality was due to the fewness of small children in a population consisting largely of adult plantation laborers. In Nigeria, it will be remembered, the majority of carriers of mature parasites were young children.

This locality afforded the further advantage of excellent laboratory facilities; there we could prepare doses, examine bloods, and dissect samples of the numerous anophelines collected in the dwellings of the people.

An essential requirement in an experiment of this kind was, obviously, a proper control of the people who received the plasmochin. They had to be dosed twice a week and it would not do to leave any large proportion of them untreated, else these would infect innumerable mosquitoes. Imagine how many *Anopheles*

gambiae one carrier with skin unprotected from bites and blood loaded with gametocytes might infect during one night! Sporozoites in the salivary glands of the insect, like bullets in a machine gun, may be exhausted by repeated discharge; but they may be replenished by a fresh bite from the human carrier. The wayfarer, too, had to be looked out for; he might come from a village distant from the experiment, lodge for a night in some cabin, and infect many mosquitoes. My colleagues, Dr. Rice and Mr. J. Y. Brown, the latter coming to us from the Medical Department of Lagos, were most skillful in making domiciliary visits by night, surprising, and, if necessary, dosing any chance intruder on the experiment.

Native domestic relations were not complicated in that region, a circumstance which did not always add to the simplicity of the experiment. Wives were quoted at a nearly uniform price of twenty-five dollars apiece, and could be bought on the installment plan. Naturally, their numbers were not uniform, and an influx of untreated wives might disturb the balance of the dosed and undosed. Malaria is no respecter of the human sexes. To the anopheline, a female of the species is quite as good a source of blood as the male.

In spite of difficulties we obtained results which to us appeared significant. The sporozoite index of the anophelines decreased during the plasmochin dosing, and promptly went up again when it was discontinued. We did not expect it to decrease wholly: we had the migration of anopheles to take into consideration as well as that of the people.

It seems possible to reduce the sporozoite index by a plasmochin treatment of a population, but it is doubtful if malaria control could ever depend wholly on such a measure. There are too many people— and mosquitoes—coming in and out. Such treatment might count where the drug used is also the one employed for the treatment of malaria patients, or where the population is under strict control, as on a plantation or in an army.

In Liberia there were many cases of malaria among the plantation employees, but the disease was not serious enough to in-

terfere greatly with the plantation work. Many of the employees were "salted"—that is, so long exposed to malaria from infancy up that they could partially withstand the effects of the parasite which infested their blood. We depended largely on screens for protection against malaria during our stay on the plantation. Some of the houses there were excellently designed for comfort in the tropics. The large living room was upstairs, almost open on three sides and well screened; so that one could get the shade, the lightest breeze, and full protection against mosquitoes. The climate was not an uncomfortable one—rather less trying than in many cities of the lower Mississippi Valley during the summer.

Drainage as an anti-malaria measure would be rather difficult on this plantation. There is much water, and a very small collection of it will serve *gambiae* about as well as the shallow seepages serve *maculatus* in Malaya. And, like Malaya, West Africa is particularly rich in malaria-carrying anopheline species, among them *funestus, nili,* and *pharoensis. Nili* may have been associated with the Nile in the region from which it received its name, for in Liberia it was particularly a river species, abundant in the Dee, a crocodile-infested stream, which flows through the Firestone plantation. In some parts of Liberia, like Cape Palmas, it rains every day, and the whole country seems particularly adapted to mosquitoes.

During the recent wars, we have maintained several military camps in West Africa, and our army medical officers are to be congratulated for protecting our troops so well in a country where tropical disease, especially malaria, is plentiful; for on arrival there they found many anopheles loaded with sporozoites and many natives already infected with the disease. One is reminded of the Hebrews in the fiery furnace: almost a miracle would be needed to keep a large body of troops long unfevered in a malarious country like West Africa.

CHAPTER SEVEN: GREEK MACEDONIA

My work in Greek Macedonia was undertaken soon after my visit to Equatorial Africa. Very interesting it was to compare these two regions, so unlike in topography, climate, and populations, but so similar in being afflicted seriously with malaria.

The great forests, common in West Africa, are almost lacking in the part of Macedonia where I was stationed. The hills and mountains are mostly brush-covered, although in the valleys between them one often finds clumps of large sycamores, the descendants possibly of classical ancestors. The ancient Greeks, we read, did not plant many forest trees, preferring the fruit-bearing olive and fig, but the modern Greeks are encouraging forestry. One often sees mountainside plantations, occasionally evergreens, struggling against their two mortal enemies, goats and brush fires. The climate of Greek Macedonia was about as warm as that of Tennessee in America. We had real winters, with snow and occasionally ice thick enough to bear the weight of a man; and real summers, too, long and warm enough to breed plenty of malaria. The rainfall was far less abundant than that of Equatorial Africa and less uniformly distributed. We experienced several droughty summers when the countryside was nearly dry and the streams and pools were comparatively few, often so concealed in grass, reeds, and brush that only the mosquitoes, searching for a place to lay their eggs, could find them. There were more extensive watery areas in certain localities as in the valleys of the Struma and the Nestos rivers, or in the Pass of Thermopylae; but much of the land was sun-baked and comparatively waterless.

The peoples and their history offer perhaps the greatest contrast. In Equatorial Africa the centuries had left but little impression on civilization, while in Greece the Age of Pericles afforded what was perhaps the most rapid advance in human culture ever experienced in the history of the world. But when the great plague struck Athens, Pericles was as helpless before it as would have been the crudest chieftain. The Greeks practiced medicine,

but the cause of the disease they were more prone to attribute to the arrows of Apollo than to the stings of insects.

The ancient Greeks suffered from malaria even if they did not know how to cure or prevent it. There are references to the malady by classical writers, so detailed that one cannot doubt they were writing about malaria. The Fates (or was it the Furies?) played a mean trick on the ancient Greeks in afflicting them with the disease, then planting the sovereign remedy for it, quinine, on the other side of the world in the mountains of Peru.

History, ancient and modern, has left its stamp everywhere in Greece. From our house in Cavàlla (the ancient Neopolis of classical and biblical writers) one could see in the farther distance the peak of Mt. Athos, rising nearly six thousand feet above the Aegean Sea; the island of Thasos, where Thucydides wrote his history; and beyond it, farther in the direction of the Dardanelles, the Samothrace of the Winged Victory. A Roman aqueduct dominated the foreground, stretching across the valley to a lofty hill, the site of a Turkish palace dating from the times when Constantinople ruled the land. About twenty minutes away by automobile one saw the ruins of Philippi, where St. Paul released the prisoners, and just beyond it the Plain of Philippi, where the Romans fought their battles—and I do not know how many peoples have fought there since. Greece is not satisfied with its wealth of history but has to keep on making more. She was draining the Plain when we were there—fighting the swamps and the malaria prevalent in it.

At the time of our visit in Greek Macedonia (1932-1936), the International Health Division of The Rockefeller Foundation had many anti-malaria workers in Europe. There were units in Spain, Italy, Albania, Bulgaria, Turkey, and Greece. Dr. M. C. Balfour was in general charge of the work in Greece, and had as his assistants Mr. D. E. Wright, a sanitary engineer, and Mr. Ray Shannon, an entomologist. In Greek Macedonia I had as colleagues Dr. J. B. Rice, formerly director of the hospital of the Firestone Plantation in Liberia, Dr. Henry Carr of the Foundation, and Drs. Valaoras and Mandekos, young physicians of Greece. It

was the excellent custom of the Foundation to employ local doctors in order to train a staff of men prepared to continue the work after the Foundation had left the country. Dr. Mandekos is now doing anti-malaria work in Greece, despite the difficulties caused by famine and war. Although widely separated, the Rockefeller units in Europe used to coöperate fully, sometimes holding meetings to talk things over.

One of our earliest tasks in Macedonia was to study the anopheline mosquito species there and to determine which one of them was doing the most of the malaria-carrying. There were three species—*superpictus*, *elutus*, and *maculipennis*—at once under suspicion; for their larvae were plentiful and their adults were common in the dwellings of the people in the malarious regions. Their breeding places varied, so that it would require a different disposition of anti-larval activities to combat them. *Superpictus* bred in clear springs and streams, like *minimus* in the Philippines, while *maculipennis* frequented pools and ponds of more stagnant waters. *Elutus* was often found associated with *maculipennis*, but could tolerate brackish waters and often occurred in vast areas of water near the sea where the other species were rare or lacking. *Maculipennis* is no longer considered a simple species, but a group of varieties, some of which are regarded as dangerous carriers in some parts of Europe; and one distant cousin is responsible for much malaria-carrying in western America. Two or three varieties occur in Greece, and we were naturally interested to know if they were important vectors of malaria.

As we have seen in our description of *gambiae*, the choice of hosts of a mosquito counts for a great deal in its malaria-carrying activities. In Greece we made much use of the precipitin reaction to determine the source of the blood found in the stomach of the mosquito, a method first applied to insects by Uhlenhuth and Weidanz in Germany.

The first requisite for this test is a stock of precipitating sera. The process of preparing one such serum, a human-sensitized one, for example, is as follows: An animal, commonly a rabbit, is repeatedly inoculated with human serum; its serum eventually

acquires a new property, that of forming a precipitate when brought into contact with human blood. Other rabbits are likewise treated with the sera of other animals; one chooses for malaria work the sort of domestic animal usually associated with man; we used in Greece cows, horses, pigs, and sheep. If the mosquito stomach contains human blood, its serum will form a precipitate when brought into contact with human-sensitized rabbit serum; if it contains cow blood, with the cow-sensitized one and so on. If in place of the mosquito blood-meal we used blood from a suspected weapon in a murder case, a precipitate with the humanized rabbit serum would indicate human blood and no other, for the reaction is sharply specific. We did not have to prepare our sensitized sera; we could buy them ready-made and preserved in glass vials. Before use we diluted them highly with a salt solution, so that a little went a long way.

With this technique we could classify in one day hundreds of mosquito blood-meals, and our conclusions were based on the examination of thousands of specimens. In reckoning our percentages, we included only mosquitoes which reacted with some precipitating serum, thus eliminating specimens, not at all uncommon, containing blood too far digested and lacking enough serum to afford a sharp reaction. It appeared that *elutus* possessed by far the highest percentage human-positive, nearly fifty percent; *superpictus* was well below it; and our varieties of *maculipennis*, hardly ten percent.

The sporozoite index of *elutus* exceeded that of the other species, although it was very low—only about two percent as compared with the six or more of *gambiae* in Africa. Our Greek varieties of *maculipennis* were the lowest of all, dropping to nearly zero during the less malarious years. All three species were common in human dwellings and all proved to be definitely susceptible to malaria parasites.

On the whole we concluded that *elutus* was the most dangerous species in Greece but that *superpictus* could not be disregarded. The country is fortunate in having no *gambiae* to contend with, for this species has a preference for human hosts of

nearly one hundred percent and is otherwise well equipped to make a formidable vector of malaria.

The precipitin test may be modified in different ways. One can dissect the mosquitoes as soon as caught and place the stomach blood on filter paper. These "blood spots" can be dried, kept for many days, and eventually transported to a central laboratory for identification. There the blood is soaked out in a salt solution and is ready for testing.

The blood preferences of a given species as shown by the precipitin test would occasionally vary somewhat from locality to locality. In health resorts in Macedonia we sometimes found a higher per cent human positive among *maculipennis* than on farms, obviously because there were fewer domestic animals in the health resorts convenient for biting. And there is reason to believe that a species of anopheles may become more dangerous during famines when a large proportion of the domestic animals ordinarily available for anopheles has been slaughtered. It is interesting to speculate whether a species of mosquito could be made to acquire a taste for an animal to which it is not naturally inclined; for example, could domestic animals be made so abundant and convenient to *gambiae* as eventually to divert the females from their favorite food—human blood?

Dr. Rice and I devised a simplification of the precipitin test which enabled us to perform many hundreds of tests in one day. We also used the test to determine if an anopheline commonly changes its hosts. We found many specimens in which the salivary glands contained sporozoites—this proved that the insect had bitten a human gametocyte carrier—and at the same time we found the stomach full of the blood of some domestic animal; so we knew that the insect had changed its host, although many days and many feedings may have intervened between the human and the domestic animal bitings.

We also found this test useful where we had least expected it to be—in determining the efficacy of screens. We sometimes wish to know if the inhabitants of a screened village are in the habit of sleeping out at night, which they might do to avoid the heat or to

guard animals or crops. So early in the day, we collect a few hundred of blood-engorged anopheles in the stables or from any locality in the village outside the dwellings and test their blood-meals. If any considerable proportion of these prove to be human, we suspect that the people are sleeping outside the screens. Of course we should employ as a control an unscreened village, to guard against a possible error through flight of the anopheles from some unscreened source. We have never gone so far as to recommend the test for detecting thieves coming from some unscreened locality and prowling in the village at night!

The length of flight of malaria-carrying mosquitoes is, obviously, a matter of importance. When the malaria worker undertakes to protect a village by the destruction of the dangerous mosquitoes in its environs, he needs to know how far out his work must extend.

We did some experiments to determine the flight-dispersion of *elutus* in Greece. We chose for a testing place a large pond close to the border of the Aegean Sea, where an admixture of sea water rendered the pond brackish and very favorable for the breeding of this species. We caught vast numbers of adults in a village (Nea Carvalhi) close by the pond, sprayed them with a weak solution of an aniline dye—so weak as to be harmless to the insects—and released them at the margin of the pond. Several days later, we captured considerable numbers of the same species at a village, a suburb of Cavalla, situated nearly three miles away. We found a few aniline-stained, thus proving that they had come from the border of the pond where we had released them.

This sort of test is often employed to determine the range of dispersion of a mosquito species, but in our experiment was subject to one source of error. A much-traveled road connected the pond and the suburban village, and it was possible that the few anopheles we found had "hitchhiked" in some vehicle or on the back of some animal; so we made a second observation to test the validity of our staining experiment. This pond occasionally dried up and became nonproductive of anopheles, an event which happened in August during one year of our observations and in Sep-

tember the next. Since abundance of *elutus* in the suburban village varied in proportion to the number observed at the breeding place, it appeared very probable that our staining test was reliable and that *elutus* was actually dispersing in considerable numbers from the pond at Nea Carvalhi, where it bred, to a village three miles distant. This brackish pond, by the way, was supplying *elutus* and intense malaria to five villages in its vicinity —it was the Hydra of the region. Indeed, somebody has even suggested that the notion of the mythological, many-headed Hydra owed its origin to a malaria-breeding pond like the one at Nea Carvalhi.

The flight-range of anopheles varies, naturally, with species and locality. In the United States we thought a community reasonably safe if separated by a distance of a mile from the breeding place of *Anopheles quadrimaculatus;* in India a half-mile used to be reckoned safe. Much depends, naturally, on numbers as well as species and locality. A half-dozen infected *gambiae* might cause havoc in a military camp a mile or more distant from a malarious village in Africa. It is difficult to account for many of the migrations of anopheline mosquitoes. In addition to their chief stimuli, the search for places to get blood or to lay eggs, we have to deal with their instinct for dispersion, which often incites them to make apparently unaccountable journeys by land and sometimes to undertake long and unprofitable excursions far out to sea.

We began our surveys of malaria in the population of Macedonia early in 1932, beginning with village children in the vicinity of Cavalla. Blood-positive indexes were exceedingly high, some of them ranging from sixty to ninety percent. They were probably unusually high that spring, because the previous year had been very malarious; most of the parasites we found in the children had been carried in their blood over the winter from the year before.

During this and subsequent years, we made many surveys in Greece and found malaria indexes comparable with those of Africa. The prevalence was not generally so high—large cities and mountain localities in Greece were nearly free from the diseases

but the people suffered more severely from it. Apparently they had not become so tolerant of the parasites as in Africa.

The curve of malaria prevalence from year to year varies more in Macedonia than in Africa, much depending on the annual rainfall. We experienced one long period in Macedonia, 1932-1935 inclusive, during which summer rains were below normal and the number of anopheles and the amount of malaria of many villages greatly diminished. The diminution of malaria and of anophelism during these years seemed to be due wholly to lack of rain; for certain control villages situated in the vicinity of more permanent breeding places showed little decline. In Greece we found no natural "cycles of malaria prevalence" independent of the weather.

During this dry period, Drs. Carr and Mandekos surveyed many villages to ascertain the malaria morbidity rate, and found scarcely two percent of the people whom they could classify as "sick abed" with malaria. When the rains recommenced in 1936, the sick rate went up, as did the parasite index. During these periods of lowered transmission many persons, especially infants, escape infection and fail to acquire a tolerance of the effects of malaria parasites or fail to keep up any tolerance already acquired; so that when anophelism is renewed, a severe epidemic may take place, for the parasites find a large increase of highly susceptible persons in the population. When the droughts are accompanied by famine, as in some regions in India dependent on irrigated rice, the epidemic may be very severe, since it finds a hunger-weakened population. There was no famine in Macedonia during the time when we were resident there, for the chief crops —wheat, melons, and cigarette tobacco—were not fatally affected by drought.

The Greek villagers were very coöperative. They were always willing to offer a drop of blood, not for drachmas but for tablets of quinine. The Greek government supplied tons of free quinine to the people, but there were so few tons and so much malaria that the quantity given away was not enough to have much effect on the amount of sickness, at least in our neighborhood. So we

needed no persuasion other than tablets of quinine to collect the people for examination; they knew the value of quinine and were eager for it. During the periods when the schools were in session, children were always available; but scarcely less so during vacations. Then we had only to ring the school bell, and within a half-hour or less we had plenty of children, some alone and some carried by their mothers or led by hand. Once when we gave some children their choice of sweetmeats or quinine tablets, they chose the quinine. Like Oliver Twist, they were always ready for more. Only here the children may have been coached by their parents as to the proper choice—I am not sure.

Certain health resorts situated near hot springs undoubtedly increased the prevalence of malaria in certain parts of Greece, especially among poor people who could not afford the more expensive "cures." We visited one such resort at the Pass of Thermopylae, famous for battles ancient and modern. The most notable battle of all, perhaps, has never ceased over the centuries, that of the land against the sea. From the mountains above the pass issue streams of highly mineralized water, some of them hot—the Thermopylae of the ancients. This water evaporates in the pass, and the salts, left behind as a stony crust, build up the land. At present the pass is so wide that it hardly deserves the name—the land is conquering the sea.

People come to these warm springs to get cured of rheumatism and go away with malaria, for the pass is swarming with *elutus*. The houses there are screened after a fashion, but a poor fashion indeed. We visited a house there just at dusk, a time when anophelines are striving to get out-of-doors for their nightly prowl, and we found the screens so defective that they were keeping more mosquitoes in than out. Here the people did not seem to be aware of the relation of mosquitoes to malaria. Malaria is recommended as a cure for some diseases, syphilis, for example, but is a doubtful remedy for rheumatism.

In the Plain of Philippi there are also warm mineralized springs, where people come to be cured of rheumatism, many camping in their wagons during the cure. The mud baths are

much prized—small individual puddles where the patient sits in mud up to his ears; of course he would leave some bare skin for the anopheles to bite! Malaria is rife in that neighborhood, but screens or other means of excluding anopheles were lacking. Possibly Philip of Macedon resorted to these baths; they were within walking distance of Philippi. We used these warm springs as breeding places for *Gambusia* minnows; they were very suitable for the purpose, the fish breeding in them summer and winter. I trust they reduced the malaria danger somewhat.

A person infected with malaria may retain parasites in his blood for many months or even several years; so that when one finds an adult or an older child malaria-positive, it is often impossible to determine when he contracted the disease—information especially valuable in some kinds of malaria research. In infants we can determine the time of infection much more accurately; the date of birth is shown in the village registry, and an infant is rarely born with malaria parasites in its veins. The few cases which occur are due to some pathological condition which allows the passage of parasites from the infected mother to the unborn child. We found one case in Greece where the infant was only a few days old, but the parasites were mature. So they must have come from the mother, for the time after birth was too short for anopheline infection and the maturation of parasites.

We had no difficulty in finding plenty of infants for examination, the mothers being glad to bring them. Sometimes they were disappointed if the examiner visited their village and overlooked their babies.

We found the infant surveys especially useful in measuring the amount of malaria transmission during different months of the year. The autumn transmission was of especial interest, for then transmission definitely declines while the sporozoite index is still high. This apparent anomaly appears to be due to the fact that the mosquito begins to store fat in its body early in the autumn and otherwise prepares for winter, and is then less inclined to bite man. Eventually, the male anopheles fertilize the females, and the spermatozoa are deposited in a special container

in the abdomen where they remain living until spring, when they are ready to fertilize the eggs as they are deposited on the surface of the water; the male does not survive the winter. During the colder months the females spend much of their time in stables among domestic animals, but they may fly about, change residence, and even deposit a few eggs. We have found anopheline eggs in Macedonia during every month of the year. They take blood freely from the animals, and in March lay quantities of eggs, sometimes more than one batch per female, and then die.

We sometimes found malaria parasites in the stomach and salivary glands of anopheles during the winter, sometimes as late as March of the following spring. We discovered many of these winter-infected specimens in a certain village which had suffered from a late autumn epidemic—one of the few instances where I found a blood parasite index of one hundred percent among children in Greece. These winter parasites often showed signs of degeneration, but we could not be sure whether some of them might not be capable of transmitting malaria if the infected mosquitoes ever bit man. Again, it is possible that the anopheles might become infected in winter if they bit human beings then, for man often carries abundant parasites in his blood during the whole cold season. It seems unlikely that mature parasites would often form in winter, because they grow so slowly in mosquitoes at low temperatures, but we wanted a further test.

To determine if winter transmission commonly occurs in Macedonia, we examined many infants born after the first of November, who, naturally, were exposed to mosquito bites in their homes during the entire winter. We found not one positive for malaria parasites except the one case I have mentioned—undoubtedly infected by its mother before birth. It seemed then, that however active the anopheles during the cooler months, they rarely visited dwellings or fed on the blood of human beings in winter.

A people known as the Vlachs (the ancient nomadic Vlachs of history) gave us a second source of evidence regarding winter transmission of malaria. These at present are a shepherd tribe,

who spend the summers with the flocks in the high cool mountains and come down to the valleys only during the winter. Their journey to the lowlands was a regular autumn event. The main road passed our residence in Cavalla, and we often saw groups of Vlachs dressed in outlandish costumes and driving their herds as they passed by on their way down the mountain. Small children, chickens, and various other possessions were tied to the backs of horses, oscillating precariously on their high perches. "The Wobblers" we used to call them.

There was little or no malaria in the mountains, so that if these people got malaria it must come during their winter stay in the lowlands. We examined Vlach bloods and found them parasite-free. Thus we had no evidence of any winter transmission, although the Vlachs sometimes wintered in very malarious villages.

We had a third source of evidence, which I shall describe more fully because it is of much epidemiological interest. During World War I, an extensive epidemic of malaria occurred among troops in the valley of the Struma River near Salonica. The English and French held one side of this famous stream and the Germans and Bulgarians the other, while pestilence held both sides and spread to all the contending armies. The armed troops had literally to stop fighting each other and to take care of the sick, and if one or the other side had had means of preventing malaria, it would have secured a material advantage in the war.

We were not present in Greece until the 1930's, but we had acquaintance with the medical directors of British, French, and German armies, and we asked them if there had been any evidence of winter transmission among their troops. The answer was almost entirely in the negative, and one informant assured us that even in Algiers in North Africa, a country with which he was very familiar, there was no evidence of winter transmission of malaria. So here was a large-scale experience which confirmed our conclusion, that as a rule there is no significant winter transmission of malaria in European countries as far north as Greek Macedonia.

Transmission certainly begins there as early as May and, very

probably, sometimes continues into October, so that it occurs during about five months of the year; but our investigation—in which the examination of infants proved very useful—showed that the bulk of it occurs during the period of July, August, and possibly part of September—the warmer months of the year in that region. Of course, one would if possible continue anti-mosquito work during the whole of the summer; but if time and materials were lacking, one might do effective service even when his anti-mosquito work (drainage, larvicides, and spraying) were confined to July, August, and September. Since the time we were in Greece, important improvements have been made in the means of combating mosquito vectors of malaria, and it may be that a winter or early spring attack on the anopheles will eventually be found feasible—especially in preventing, or at least delaying, the activities of the summer broods.

During 1936 we made many examinations of the infants in thirteen villages, in order to test as many as possible of the infants who were exposed to malaria during the summer of that year, which in those young children was the first summer of their lives. It proved that nearly two-thirds of them had become infected. Since adults suffered as many anopheline bites as the infants or perhaps even more, we see how much transmission was going on during that very malarious year.

One naturally seeks to know what became of these infected infants. One of the Greek members of our staff, Dr. A. G. Mandekos, made a special investigation of this point, and found that the greater part recovered. This was a time of peace, the country was prosperous, and there was money for food and for medical attendance. One wonders what has happened during the recent war. Malaria infection probably went on unabated, but the supply of food and medical service undoubtedly diminished. Famine and malaria coöperate, so that the status of the people during the war was far worse than at the time of our investigation.

It has been suggested that malaria was a large factor in the political decline of Greece. From our modern data, it appears that the health of a people like the Macedonians will stand up well

in spite of high malaria infection provided patients are well nourished and receive medical attention; but with war, poverty, and famine on its side, malaria may have contributed much to decline during certain critical years in the nation's history.

The exchange of races which followed the Greco-Turkish war of the late 1920's doubtless affected the prevalence of malaria among the villagers who were settled in Greek Macedonia. There was probably malaria in the parts of Turkey whence they came, but it is likely that they found more of it in Greece, anyhow in the valley of the Nestos River, where many of them settled. Nea Carvalhi illustrates well the history of one such village in relation to malaria. The village owes its name to Carvalhi in Turkey, whence the inhabitants came to found a new home in Greece. They brought with them, as their most valued possessions, the bones of their patron saint, which they enshrined in the church of their new village. I am sure they were not well guided when they chose a site for their new home, for they put it close beside the *elutus*-breeding pond I have described in the discussion of the flight-range of anopheles. The villagers suffered severely with malaria; at one time, their parasite and spleen indexes were nearly eighty.

The Greek government undertook to drain this pond, but it lies so near the sea level that it lacks a place for disposing of the water. The engineers sought to prevent the entrance of new water into the pond by excavating interception ditches along its upper shore. But the perverse torrents, flowing down the sides of the hills, sank into the porous soil under the ditch and emerged on the other side, thus literally diving under the intended interceptor.

Probably the only practicable way of draining the pond is to construct a dyke along the sea and then pump the pond dry with engines—a technique which has served to reclaim much seaside land in Italy.

The ground in that locality is doubtless made more permeable by stones and gravel washed down from the hills. In many Greek streams the water, flowing in goodly volume some miles from the

coast, disappears when it reaches the ground near the sea, reversing the behavior in our western streams, which commonly grow larger as they near their mouths. In our larva surveys in Greece, we sometimes had to go far upstream to find any water.

The Rockefeller Foundation did much for the health-education of the Greek people. Dr. Balfour sent nurses into villages, who not only obtained for us some much-needed information about the food and health habits of the people, but also taught the people much about wholesome living. Mr. D. E. Wright gave them many practical demonstrations in the method of protecting their water supplies against intestinal parasites. It was Mr. Wright who did anti-malaria drainage on the ancient battlefield of Marathon.

Many of the villagers, like Pericles, knew much about politics, I fear, but little about the transmission of malaria. One day when we made a brief halt in a village of the Plain of Chrysopolis, the conversation turned to the subject. The village magistrate said that malaria is due to the water. "No," the priest maintained, "it is carried in the air." We might have said, "Gentlemen, you are both right. If there were no water for mosquitoes to breed in and no air for them to fly in, there could be no malaria."

CHAPTER EIGHT: CYPRUS AND TURKEY

While we retained headquarters in Greece, we made two visits to Cyprus, one in 1935, the other in 1936. Greece and Cyprus are very similar as regards malaria; both are in large measure infested with the disease and both have to contend with the same mosquito vectors. Cyprus has a population largely Greek, but with an admixture of about twenty percent Turkish; it was a Turkish possession until 1914, when it became a British colony.

In topography and climate the countries differ widely. Cyprus is a large island situated in the northeast corner of the Mediterranean, its outline suggesting that of an animal skin tacked up to dry. The island is about 140 miles from tip to tip, and to the east it is distant only about fifty miles from the warm, dry plains of Syria, a circumstance which affects its climate. Lying between two mountain ranges of Cyprus is a broad plain, the Messaoria, about sixty miles long and containing many of the cities of the country and much of its agriculture. There we did the greater part of our anti-malaria work.

The climate of the Messaoria is very hot and dry in summer; the rainfall of June, July, and August is almost nil, and that of September very low. The greater part of the rain occurs in winter, when the hills and mountains fill with water, which they rather niggardly dole out to the plains during the summer. As is the case of many lands in the Mediterranean basin, much of this winter-stored water is essential for irrigating the summer crops. Reservoirs are constructed to conserve the water of the winter rains, and deep wells are common. One of the characteristics of the Cyprian landscape is the multitude of tall windmills used to draw water from these wells, many of which have given place to Diesel engines, more reliable if less picturesque. An ingenious method is employed in some localities for getting out ground water without pumping, a method I have never seen in any other country. A chain of wells is dug along a suitable slope, and their bottoms connected by a tunnel. The water collected in the wells

passes through this tunnel from well to well, and finally issues to the surface of the ground as a flowing stream. In some localities, artesian wells are sunk. Possibly at some future time but little of the water stored in mountain and hill will be allowed to return unused to the sea. It may be that some of the ground water of Cyprus comes from the neighboring Taurus Mountains in Turkey. Will some future time see international quarrels about underground waters, such as we now have about irrigating rivers?

The greater part of *superpictus*-breeding water is found in streams, some always flowing and some reduced in summer to a chain of pools. Most of the water is full of green algae, which cover the stones and form occasional masses in the pools. The more abundantly flowing streams are commonly found in the vicinity of mountains or hills, and often resemble bright green ribbons stretching through the brown plains. These streams and pools are almost always well populated with the larvae of *superpictus*. At first view one would say that this water is the last place in the world to look for the source of "swamp fever"; but scoop out a little hollow among the alga-covered stones, wait a minute or less and you may see anopheline larvae rise to the surface of the water and dart to shelter at the rim of the pool. A village situated at the border of the stream may show many anopheline adults in stables and dwellings and numerous cases of malaria among the people.

The amount of malaria in Cyprus is comparable to that in Greece. The larger towns and cities are now nearly free from it, thanks to the activities of the British health authorities, but villages are still very heavily infected. In our survey of village children we commonly found blood parasite indexes of seventy percent; our survey of 1935, consisting of over a thousand examinations, gave average indexes of thirty-six parasite infestation and over forty percent spleen enlargement. Malarial sickness was not uncommon, sometimes rising to epidemic proportions; and, like the people of Greece, the Cyprians had acquired no very effective amount of tolerance of the malaria parasites. Cyprus is an

example of a condition we find in many places in the world—intense aridity associated with a high degree of malaria.

Superpictus, the chief malaria vector in Cyprus, affords a most interesting study in malariology. In Cyprus its sporozoite index is seven and one-half percent, greater than that of *gambiae* in Africa, and its percentage of human among stomach bloods nearly six times that of the same species in Greece. Evidently, this species is closely associated with man, and its high sporozoite index shows that sufficient people are affected with malaria to afford plenty of carriers of mature parasites to infect the mosquitoes. We found one village child with about as many gametocytes in its blood as it had white corpuscles, the highest percentage I have ever found next to that of the famous Chinese of Malaya.

Possibly the dangerous character of *superpictus* in the Messaoria is due to the fact that this region is nearly denuded of forests. The larvae of the species have plenty of sunlight and the adults, lacking other refuge, are more prone to seek villages as their daytime resting places. In ancient times, it is said, Cyprus enjoyed many more forests than at present, areas now nearly desolate being dotted with villages. Now, as in Greece, the hills are often merely brush-covered. We once visited a hill of this kind, where some of the brush-clumps have a curious history. It seems that this locality was once the cemetery of an ancient people who wished to leave their dead in graves which would not be desecrated. So they dug deep, dry wells, fashioned tunnels which led out from their bases, and placed the dead within them; then they filled up the wells with soil. But the brush grew higher in the loose soil which filled the wells; modern archaeologists were therefore able to find the graves. Thus nature has betrayed man in pointing out the resting places of his dead.

Possibly one explanation for the closer association of man with anopheles in Cyprus can be found in the nocturnal habits of its domestic animals. There is no predatory animal larger than a fox in Cyprus, so that cattle are allowed to feed outside of the villages. Naturally, the mosquitoes which stay in the villages are the

more likely to attack man at night; there are fewer rival sources of blood.

In Macedonia cattle are usually confined in the villages at night because of wolves, which are likely to attack them if they are allowed to roam in pastures away from the protection of the village. Thus the mosquitoes have cattle to feed on, abundant and convenient to dwellings of man. Although one does not think of wolves as an anti-malaria measure, it is quite possible that such is the case in Greece. We must admit, however, that this protection is not particularly efficient.

Many years ago it was noted in Italy how domestic animals deflect mosquitoes from man, and it was seriously proposed to guard villages from malaria by surrounding them with cordons of pig sties. I believe the experiment failed, probably because there were so many mosquitoes and so few pigs.

In Cyprus *Anopheles elutus* is not so plentiful as in Greece except in certain localities near the sea. One seaside city, Larnaka, is famous for its production of salt and also for the intense malaria which once prevailed there. I searched many pools of water in Cyprus for some variety of *Anopheles maculipennis*, but found not a single specimen. It is curious that such a widespread and adaptive species has not gained a foothold everywhere in the Mediterranean basin; it may be that conditions in ships are rarely favorable for anopheline-carrying. Quite possibly *maculipennis* will eventually reach Cyprus by airplane—if it has not already done so.

The best control measure for malaria in Cyprus would, at first glance, appear to be a simple matter of engineering—to divert the scanty water to the thirsty land. But the mosquitoes breed in irrigating ditches, and the health engineer may be restricted by the presence in the land of many ancient and highly controversial water-rights. One appreciates what a blessed thing is rain, which is indifferent to human laws and falls on the just and unjust alike. Again, the winter torrents may undo much of the work of the engineer; swift water may carry sand and stones which can batter down even a firm stone wall.

Engineering may eventually solve many of the health prob-

lems of Cyprus, as it already has solved several of them. Near Famagusta, an important seaport, there was once a lake which was the source of much troublesome mosquito breeding. (Famagusta, by the way, claims to be the city which Shakespeare chose for the last sojourn of Othello and Desdemona.) Drainage was attempted, but the level of the lake is too low for successful disposition of the water. Then the agriculturists attempted to stock the vicinity with certain trees supposed to require a liberal amount of water for their growth—a drainage measure of doubtful efficacy even in swamps with comparatively little water in them. Finally, other measures failing, the engineers simply pumped out the water every spring. There were no summer rains to refill the lake, and thus the malaria problem of that city is solved. Other towns situated at more convenient levels have been protected by simple drainage or tiling, but the malarious villages are scattered over such a wide area that hundreds of miles of drains would be needed to protect them—a measure almost impracticable on account of the expense. The villages themselves are often small and have little income, so that the government could expect but little local help to bear the financial burden.

Drainage would be very expensive in one village we surveyed, where a small stream flows over a rocky bed; there a channel would have to be blasted out in order to carry away the water of the mosquito-breeding pools. This village has an interesting history. Many years ago, before the connection of mosquitoes and malaria was even dreamed of, this locality was chosen as the site of a British army camp, for it was apparently a very healthful place, among hills and clear-flowing streams. I know of no record as to how the soldiers fared, but from the size of the local cemetery, I can make a guess. Certainly there is malaria in the village now.

For many years at least, larvicides will have to be freely employed in Cyprus to help liberate the land from malaria. Larva-killing is far from a perfect measure; for although the reagent used may quickly destroy every larva in a breeding place, the eggs are not killed, and in ten days or so these hatch and the treatment has to be repeated. The new larvicides may help much. During 1943,

when I was experimenting with DDT in the streams of Tennessee and Arkansas, I used to think of the very accessible Cyprus waters, where this larvicide would be effective; possibly it is being used there today.

An interesting village in regard to malaria control is Trimithi, situated on a mountain slope facing the sea—an unlikely place for malaria, one might think. I surveyed this village in company with my colleague, Mr. Mehmed Aziz, Chief Sanitary Inspector of Cyprus. The only apparent source of mosquito breeding was a tiny stream, flowing down the mountain close by the houses. It contained numerous small pools, harboring larvae of *superpictus*. We found a few adult anopheles resting in the houses, the common habit of adult anopheles in the daytime. Mr. Aziz was adept at finding ladders and searching the high ceilings; he found only two or three specimens of *superpictus* on them, but eventually discovered a fair batch on the moist walls of the village bathhouse.

The village suffered greatly with endemic malaria. We found a parasite index of seventy-two percent among the village children; who, by the way, were too sick to help us collect the mosquitoes. Here the people themselves could do much to remedy the evil and at a very trifling expense. One man with a mattock could "train" that stream in a day or two; that is, could make an even channel for the flow of the water, thus obliterating the larva-infested pools. Then a few drops of a larvicide (kerosene would do) would destroy the larvae surviving in the channel. Probably a single small dose of the magic DDT dissolved in oil, if applied at the head of the stream, might kill all larvae halfway down the mountain.

It was probably with no thought of health that one man had made a dam spanning this stream near its source, had filled the space above it with the debris of the stream, stones and sand, and then had planted fruit trees in the moist soil above the dam. Perhaps much more of that stream could be made an orchard instead of remaining a source of sickness. But the people are not informed about malaria, and often there is no one to teach them. Then, too, I presume, many people would rather face their health problems sitting in the village coffee shop than working with pick

or mattock in a ravine. Once, in a jest, I proposed to the Chief Health Officer of Cyprus that he determine the tax rate of a village, not by the size of the people's farms or houses, but by the size of their spleens; at the same time, of course, teaching them how easily they might lower their tax rate. But people have much to learn. We once used larvicides in a clear stream in a plain which pastured many sheep. We assured the shepherds that the larvicide used could not possibly harm their flocks; but they dug new wells and kept their sheep away from the stream. Like the housewife who refused wood from a tree which had once been struck by lightning, they were not going to take any chances.

Possibly sprays which kill the adult mosquitoes in dwellings will eventually help much in solving the malaria problem of Cyprus, as of many another malarious land. Spraying would be easy for the people to do; but for a long time, probably, the government would not only have to furnish the materials but also see that the people used them. I think that if I were assigned the task of teaching people in Cyprus to help protect themselves from malaria, I would begin with a certain Turkish village, situated in the Messaoria and once surveyed by Mr. Aziz and me. We found adult anopheles in the houses and a very considerable malaria index, but the mosquito-breeding water of the vicinity was confined to several small pools, situated in a very dry plain. I would suggest to the people that they could control their mosquito breeding by means of a large sponge—there was so little water and so much dry space to put it into! Of course, there may have been more water earlier in the season, but the control of malaria in this place should be a simple matter.

A much more difficult problem in malaria control is that of Asomatos, a village near the sea, which has a very high malaria index—eighty-eight percent infected among village children. Here we have an ancient landlocked harbor, probably Venetian, connected with the sea by a canal sufficiently wide and deep for the ancient sailing vessels. The harbor itself is salt and the water unfit for mosquito breeding; but the flat shores of the harbor have become a swamp, full of reeds and tall grass. This swamp contains

numerous springs boiling up from the ground and affords an excellent place for the breeding of *elutus*. An orange plantation situated near this lagoon, like the neighboring villages, suffers much from malaria.

It was proposed to pump the lagoon dry—it is no longer used by ships—and eventually use the sweet-water springs for irrigation. But it appears that this sheltered water offers an excellent harbor for seaplanes and should be preserved. When we were debating the question, we were approached by an anxious group of villagers, who feared greatly that we were going to drain the lagoon and destroy certain reeds which were indispensable for their basket-weaving. They undoubtedly had never heard of any connection between the reed-growing swamps and their malaria. So with all these conflicting interests—health, seaplane harbor, and baskets—I daresay *elutus* is still breeding there undisturbed.

While officially resident in Cyprus I made a short visit to Asiatic Turkey. I was accompanied by Mr. Mehmed Aziz, of the Health Department of Cyprus, who was familiar with the language and customs of Turkey and was an ideal traveling companion.

We embarked at Cyprus in an Italian freight steamer—rather unexpectedly to the ship's personnel, it appeared, for they had to prepare a stateroom for us rather hurriedly; but, being ample in size and situated next to the dining room, it suited us very well. The stewards, or what corresponds to stewards in a freighter, had only to prepare the beds and remove the silverware which had been stored in the room; then we were comfortable for the voyage and free from temptation.

One curious thing about traveling in a freighter of this class was that one does not know where he will eventually land. We thought we had embarked for Mersin in Turkey, but the ship got orders en route to change its destination—owing to the demands of trade, not for the convenience of passengers—so that instead of going directly to Turkey we found ourselves traveling along the picturesque coast of Syria. We passed by the "Pig's Snout," a

high promontory extending down to the sea, and by a range of mountains any one of which we could imagine was the famous Musa Dagh of the Forty Days, and we were finally dumped at the port of Alexandretta of Syria with no preparation, not even with a stock of Syrian money. But that lack did not daunt the resourceful Aziz; we immediately took boats to the wharf, although we had no money to pay the boatman, discharged our baggage and myself on the landing wharf, and looked for a taxi. Aziz picked one up, stowed the boatman therein, and set out for a local bank to get some Syrian money, soon returning with all our debts duly paid. All this had to be done very quickly, for our train started for Turkey within an hour or so and there was only one train every two days.

We caught the train, though no thanks to me, for I was ignorant of language and money values alike. But if I had been a qualified physician I might have built up a considerable practice during that brief period of waiting on the wharf. The bystanders, concluding from labels on our baggage that we were medical and free of charge, wanted to consult me on their cases of malaria, epilepsy, and I do not remember what other maladies.

We were held up on the Turkish border for a while; not because we lacked the necessary papers, but, I suspect, because the officials lacked the necessary number of foreign travelers to practice on, as they well might when the train came by only once in two days. But we finally got through and arrived that evening at our destination, Adana, Turkey.

After a preliminary trial or two we found a good hotel, one which was clean and served good food. I had an excellent room, high up and affording a view of the snow-capped Taurus Mountains. From these mountains, I believe, the hotel brought its drinking water, the best I have found in the Near East. It was cold and soft—probably from the melted snow—and well worth the trifling cost of a few cents a gallon charged for it.

We lost no time after arrival in paying our respects to Dr. Mahmud, Director of the Malaria Institute situated at Adana. This Institute is well equipped for research and instruction in

malaria and is an indication of the interest taken by the Turkish government in the health of a rather malarious part of the country.

Dr. Mahmud showed us the things of malariological interest in and around Adana, then conducted us by rail and automobile on an extensive trip to the southwest of the city, where we found malarious villages and anopheline breeding places. On this trip we passed two historically noteworthy places: one, Tarsus, the "no mean city" where St. Paul was born, and the other a ruin now become a Turkish shrine and often visited by the people, because, as Dr. Mahmud told us, many Turks were once slain there by Armenian persecutors. We in America hear more about the persecutions of Armenians by Turks; and it was interesting to have another side of the story.

People sometimes think of Turkey as a backward country, but we saw much evidence on that trip (made in 1936) of modern influences. At Mersin, which we finally did visit, we saw a procession of school children celebrating some anniversary, all marching in the street under the supervision of the schoolmistress, who was dressed, not in the commonly pictured Turkish fashion, but as any schoolmistress might be in America on a Washington's birthday celebration in Massachusetts or Virginia.

Within a few miles of Adana we visited a modern farm, the farmhouse being surrounded by a row of tractors and other farm machinery. One tractor was being repaired by mechanics. "It is not much good," the proprietor explained, "for the thing uses up more fuel than its services are worth, but it might be of some use to somebody, so we are mending it." The proprietor, a friend of Mr. Aziz, spoke English perfectly. He had been educated in engineering in a California school.

On our return from Turkey we again passed through Syria, intentionally this time, for we wished to visit Palestine en route. We traveled by train to Aleppo, where we stopped overnight, thence by automobile to Beirut, traversing country desert-like in part but notorious for the amount of malaria it contains. Here, it appears, thousands of years of cultivation have not done so much to render the country malaria-free as a few decades have

done in America, probably because the agriculture of Syria has brought little economic betterment with it.

In Palestine much excellent anti-malaria work has been done by the Zionist government and by the British, and our plan was to learn more of this work on our way back to Cyprus. Accordingly, we took automobile at Beirut for Jerusalem, but were stopped on the way by a very courteous British sergeant who informed us that no traffic was allowed to enter Haifa, our intended stopping place en route; that an Arab had been killed by a Jew there a day or two before (or it may have been that it was the Jew who was killed), the funeral was to be held that afternoon, and it would not do to have any alien automobiles where they might get mixed up in the procession. So, together with a caravan of other automobiles, we waited by the road until finally we were allowed to proceed to Haifa.

The next day we were shown the anti-malaria work near Haifa and Acre, undisturbed by stoning (we called it "lapidations") or any other act of hostility by either party. But we consulted the authorities and were informed that it would not be wise to visit the anti-malaria work near Jerusalem during the disturbed state of the country; so we had to postpone further visits. Later I saw the anti-malaria work near the sea of Galilee.

The best way to go to Cyprus at that time was by way of Egypt; so we took train at Cairo, arriving there the next day, and from Cairo easily got passage to Cyprus.

Certainly ours was a roundabout journey from Cyprus to Turkey and back, two countries within easy cannon-shot of each other, countries whose higher mountains, Troodos in Cyprus and Taurus in Turkey, can stare at each other on any clear day. But going through Syria and returning through Palestine and Egypt showed us much of interest, not only in regard to malaria but in regard to history of the past and of today.

CHAPTER NINE: RUSSIA

During 1934 I had the opportunity to make a brief malaria study in Soviet Russia. I was a member of a party of four: Dr. L. W. Hackett, author of *Malaria in Europe;* Presto, a young Italian technician; Lazaro, our Russian guide and interpreter; and myself. This trip was undertaken in the summer and occupied about three months.

From Paris we went to Berlin, thence directly to Moscow, and there began our anti-malaria work. We continued our journey along the Volga to Saratov, by automobile and rail to Astrakan, then along the Caucasus Mountains, and finally over that range to Georgia. Returning, we visited some localities along the Black Sea—among them Yalta—finally embarking at Odessa for Turkey and Greece.

The chief object of this trip was a study of the varieties of *Anopheles maculipennis,* some of which I mentioned in the chapter on Greek Macedonia. The Russian varieties had then received comparatively little study, and we wished to learn something more about them, especially about the distribution of the more dangerous varieties. Dr. Hackett is an expert on the varieties of *maculipennis,* and Presto and I went along as his assistants.

It is easy to identify the species by a simple inspection of the adult *maculipennis* with naked eye or hand lens; but to determine the different varieties satisfactorily, it is necessary to examine the eggs. The outer layer of the mosquito egg does not present the smooth surface seen in that of many insects, but it is sculptured in a variety of patterns, often very characteristic of species or varieties. Therefore the first thing for us to do was to obtain the mature eggs and study their bands and other sculpturing. Our procedure was a simple one. We collected adult female anopheles in each locality we visited and "set" them to lay eggs. For this purpose, each specimen was enclosed in a glass tube and provided with a wet pad on which she willingly deposited a clutch of eggs, often during the first night after capture. Generally, there were

scores of them in one laying, and they could be easily examined against the white pad by means of an ordinary hand lens. We always collected the adults in their daytime resting places, usually in houses and stables, where they resort in large numbers after their nocturnal activities.

We employed a second method of obtaining eggs, that of picking them up on the surface of the water of the breeding place, where the female lays them in the natural course of reproduction. The necessary equipment and technique were very simple. The egg collector is provided with a white cloth mitten, a flat pan, and a hand lens. Arriving at the mosquito breeding place, he puts the mitten on his left hand and grasps the edge of the pan with his right, the lens being conveniently carried on a string attached to a buttonhole. With the pan he skims the surface of water where the anopheles ordinarily deposit their eggs, and pours it through the mitten. The eggs remain on the surface of the cloth, where it is easy to examine them with the hand lens.

The two methods of egg-collecting were complementary: the adult captures showed us where the mosquitoes resorted after biting and how plentiful they were; the skimming method, where they bred. The later technique rarely failed to yield us some eggs, but they were sometimes few and not always freshly laid.

Between the two methods we obtained much information. Along the route we followed we found almost exclusively the same varieties we commonly collected in Greece, until we reached a malarious locality in the vicinity of Odessa, where one of the more dangerous varieties of *maculipennis* appeared in considerable numbers.

The capture of adult mosquitoes in dwellings afforded us one great advantage. We were able to see a great deal more of the people of Russia than if we had limited our visits to ponds and streams, for the mosquitoes had entrée everywhere and we were privileged to follow them. Thus we saw, from the inside literally, aspects of Russian life hardly accessible to the ordinary tourist. Nothing of any political significance—we were not interested in that—but we visited a great variety of places: community houses

in considerable variety, the dwellings of the rich kulaks (there were a few in Russia then), the simple houses of the Tartars in Astrakan, factories and barns in great variety and number. We were especially interested in the methods of protection against mosquitoes, and we saw some good screening in community buildings; in one what looked to me like an ordinary screen was called "entomological control." There was some excellent screening in the neighborhood of the great peat mines near Moscow. We were always welcome. Indeed in one village house the people insisted on entertaining us, being willing to feed both the mosquitoes and their pursuers.

We were occasionally more formally entertained by the Russian scientists. There was often caviar; but vodka only once. On this occasion it was diluted with a kind of berry juice and was by no means a powerful drink. The use of strong alcoholic beverages was frowned on in Russia then, but maybe the drinking customs in scientific groups differ from those of military and diplomatic circles.

Once in company with a Russian scientist, we surveyed a barn in search of *maculipennis*, a mosquito which is fond of resting in stables. In a manger I found some religious paintings—icons; and had I been sufficiently quick of wit, I might have remarked to my Russian friend, "Ah, I see that you people have taken the Infant back to the manger." My friend, a man of few words, would probably have responded, "Wait until we visit the dwellings." Indeed, one house of this village had an icon in its sacred recess, still reverenced as it probably had been for generations. As I remember, however, these shrines were not very common, even in remote and unsophisticated villages.

The Russian authorities were very coöperative; the scientific people were ready to assist us, and often took pains to show us things of particular interest. In one locality in southern Russia we saw a farm for breeding monkeys to be used for research in medicine. I had once seen a lion-breeding establishment in Auckland, New Zealand, where the animals were bred for sale to

zoölogical gardens; but I hardly expected to meet with anything so exotic as a monkey farm in the shadow of the Caucasus.

How many curative springs there are in the world! One finds them everywhere from Macedonia to Argentina, and each one has some alleged healing virtue. I do not doubt that some of these waters are curative, but I suspect that their fame often depends on the idea, common everywhere, that if a mineral water is sufficiently nauseous and smelly it must be good for curing something. I have imbibed of or bathed in many of these healing waters, but I never seem to have the right disease; I cannot testify as to their healing virtues.

We visited some interesting mineral springs in southern Russia. The doctor in charge insisted on my trying one of the baths, a very shallow and conspicuous one where bathing suits were taboo. The particular virtue of this tepid bath was that it turned the skin a rosy red, probably an excellent substitute on cloudy days for the sun treatment so popular in Russia. The doctor was enthusiastic about his healing water, and lost no time in getting me into it; then from time to time he would call in someone to exhibit the patient and show how beautifully he was reddening. I was surely turning red—I felt like a chicken in the pot which the cook inspects from time to time to see how fast it is getting tender.

We were much impressed by certain swift mountain streams flowing into the valleys of a locality at the base of the Caucasus Mountains; for they were not bright and clear like the streams of the Rockies, but thick and black from the ashes they picked up in the beds of ancient volcanic debris. The water is used for irrigation and is excellent for the purpose, for it both waters and fertilizes. I did not hear of its having curative properties. It surely does not possess the power of preventing malaria, for I found the larvae of *maculipennis* flourishing in some pools black with this ash.

Except in the prevalence of malaria, I found little in common between Georgia in Russia and Georgia in America. Certainly the bread-baking in the Russian Georgia was done differently, at

all events, in one small village which we visited. The housewife built a hot fire in a sort of stone-lined well dug a few feet below the surface of the ground. When the fire had died down to coals and the stone lining become thoroughly heated, she plastered the dough in flat cakes on its surface, where it stuck until it was sufficiently baked; then it fell down into the ashes, whence it was later retrieved. I am sure that this method of baking is not common even in Russia—our Russian guide said he had never seen it before—and I doubt if one could find even corn pone baked in that way in the American Georgia.

On our voyage down the Volga, we left the river at Saratov, and went by automobile through the German Soviet Republic to Krasnakut. The country apparently suffers from deficient rainfall, and reminded me of some parts of western Kansas and eastern Colorado. But not in everything. We saw one load of hay drawn by a team of camels—a combination rare in America!

The country we saw was hardly fit for plowing, but pastured many cattle. Soon we were able to search a community house and stables for *maculipennis*. Since the people speak German, when we visited the village market—a rather lean one—we talked with them without help from our interpreter. Referring to the aridity of the land, probably, or the market, one man told me, "*Das Leben ist hier sehr schwach*" ("Life here is very weak").

We saw in Krasnakut one cleric, probably Lutheran, the only frocked clergyman I saw in Russia. There is a big church in the town, which Hackett wanted to photograph, but the authorities refused to allow him to do so, because, they alleged, the building was of "military importance"; which I do not doubt it was, if the Germans got that far east during the war.

We did not confine our malaria studies in Russia to the egg varieties of *maculipennis*. There are other anopheline species in Russia: *elutus*, our former associate of Greece and Cyprus, occurs in southern localities. We collected stomach blood-meals of mosquitoes, examined spleens of people, and visited laboratories and museums. Russia had considerable malaria in 1934. It was present in relatively small amount in the vicinity of Moscow, but

increased southward and was more plentiful near the Caucasus and below that range. Our visit was made soon after the famine of 1933, when the amount of livestock was below normal. After the supply of cattle was replenished malaria undoubtedly decreased, for then *maculipennis* and other anopheline species had more nonhuman blood to feed on. All malariologists remember the great prevalence of malaria in Russia at the time of the earlier famine of 1923, when, it is said, epidemic malaria spread as far north as the White Sea.

An epidemic of that intensity is not likely to occur again in Russia, in view of the anti-malaria activities conspicuous there. Drugs for both the suppression and cure of malaria were receiving attention; Paris green was being distributed by airplane for larva-dusting; and in one voyage along the Black Sea we saw a deckload of containers stocked with *Gambusia* minnows, which were being taken to some malarious locality in order to establish larva-devouring colonies. Generally we had no trouble in finding plenty of adult mosquitoes; but one locality we visited had been so thoroughly drained that we had to go away empty-handed. I have seen no country where there was so much anti-malaria activity as in Russia in 1934; and I assume that activity continued undiminished through subsequent years. I venture the prophecy that Russia will lead the world in anti-malaria work after this war; not only because she will control so much of the world where malaria prevails but also because of the activity, skill, and enthusiasm of her scientific workers.

Our work with varieties of *maculipennis* continued after we arrived in Constantinople. We had a few eggs left to examine after we reached the customs wharf, and we wanted to go to a hotel where we could get out our hand lenses and classify them. But the Turkish customs officer was unwilling to let this strange baggage through. It consisted of a large wooden case similar to the one commonly used in the dry goods stores of America for holding spools of thread. It was full of little drawers, which, instead of spools, contained test tubes closed at the top. In each

tube sat a female mosquito hovering near a moist pad on which were scores of black mosquito eggs. The officer was naturally somewhat baffled:

"All these medicines?"

"No, something scientific."

"Might they not be left in storage to be taken up when you leave the city?"

"No, they have to be taken to the hotel at once to be examined."

He was eager to classify the baggage, we to classify the eggs; and it was questionable if he would ever let us through. It was a fearfully hot day in August, the eggs were ready to hatch any minute—we could imagine hearing the larvae pecking within their shells—and once hatched they would be hard to classify. Finally it grew near to lunch time; we were hungry and probably so was the officer. Then he relented and let us through; but I doubt if he ever guessed what we were doing with that uncanny box.

I have sometimes been asked if the worker in so many different countries is not handicapped by language difficulties. With me such was not the case, although I am no linguist. In Malaya one soon picks up a pocketful of words of "bazaar" Malay, the lingua franca of the country employed by Europeans, Malays, Chinese, and Hindus. The classical Malay as used in literature and by educated Malays is a complete, scientific language; but the bazaar sort is shorn of most verbs and other parts of speech unessential for eating, drinking, buying, selling, and the like, and served us very well. As a friend of mine put it, "You just change what you wish to say into baby talk, then say it in Malay."

In Greece I tried to exhume some of my college Greek, but it had been forty years buried, and there was little left of it. And the pronunciation of modern Greek differs somewhat from that which my instructors taught me. If a college professor and a modern Greek should both ask Pericles of Athens for a small loan, I wonder who would have the better chance of getting the drachmas.

Of course all is easy for the tourist. All he has to do is to ask the head waiter in the hotel, who will oblige in any preferred language. Head waiters, however, are few among Greek villagers. We always had Greek doctors as interpreters; besides we did not have to talk much to the villagers, for we had little to say. Very little talk is necessary to get people to do the few things one wishes of them—to permit a spleen examination, to contribute a drop of blood, or to allow themselves to be bitten by a cageful of anopheles. In fact, the more one talks to people, the harder it is to get them to oblige. It is especially easy when one can offer a few tablets of quinine or a few coins in exchange for the permission.

In Brazil I was permitted to speak a little Spanish, although the Brazilians much prefer that we use Portuguese. I used to get children to read Portuguese to me out of their readers. I could not understand, but it amused them and me too, for the children pitied me as one congenitally afflicted: I could not speak or understand Portuguese! In Liberia, English is the official language, as everywhere else under the British flag. In India, Cyprus, and Nigeria, English is spoken by most of the educated people, as is also true in Egypt. One gets along well everywhere with English alone. It is almost the lingua franca of the world now and probably will continue to be.

In Russia we had the least difficulty of all countries, because we did not pretend even to read the language. We had along a professional interpreter who made the necessary contacts with the people, and most of the scientists we met were ready to speak in French, German, or English. How much easier it is to speak a halting French, German, or Spanish to people who, you hope, do not know the language any better than you do! You then speak more boldly and with less fear of interruptions by any interlocutor who might think it his duty to correct your faulty modes and tenses. We had little trouble in our own party. Hackett and I spoke English, of course; Hackett and Presto talked in Italian; and Presto and I got along with a sort of French. Lazaro knew English very well indeed, but had no Italian; so when he wanted

to say anything to Presto, he had to get Hackett or me to interpret for him.

A major language difficulty, troublesome whether one speaks the native language or not, is to keep the village people one is interviewing from answering Yes or No just to please the questioner, or, maybe, to get rid of him. A course in law might be useful for a malariologist, for it would teach him to avoid any leading questions. When I wanted to know if a village suffered malaria or not, I used not to ask, "Do you have any malaria here?" preferring, "What time of year do you have most of your malaria cases?" Doubtless a lawyer could suggest a much better question.

The best interpreter, who is perfectly clear when talking about most things, may become opaque when translating some point in anopheline anatomy or physiology. I remember Hackett's struggles with Lazaro when trying to describe to a Russian scientist the sculpture of the egg of *maculipennis*—its floats, frills, and micropyle, and how to get the female mosquito to lay.

Hackett maintains that I had no better success with a dialogue I once had with an interpreter on an economic problem—the purchase of a pair of boots. I needed a pair for wading in mosquito breeding places while hunting for eggs, and I found an excellent sort, Russian with high tops, for only six dollars. These I purchased at a Torgsten store—a kind common in Moscow then—which took American money and paid any change which might be owing the customers in dollars, English pounds, French francs, or any reliable foreign money. I was much pleased with these boots, so cheap and serviceable, and I wanted to know if the ordinary Russian laborer could afford them. So I inquired of an interpreter (who may have wished to be a little opaque), and this was the dialogue—according to Hackett:

"How many hours would a Russian laborer have to work to earn enough to buy a pair of these excellent boots?"

"He must pay in rubles."

"Of course, but how many hours must he work in order to get enough rubles to buy the boots?"

"He must support his family."

"Certainly, but let us suppose it is this way: *Today* he earns enough rubles to support his family for two days, so that he has a free day to give exclusively to the purchase of boots. Now *tomorrow* he will kiss his wife and children goodby, and set off for his job, determined to work steadily for eight hours. Now how many pairs of boots, or, eventually, a single boot or fraction thereof, could he acquire in return for his eight hours of labor?"

"Tomorrow is his day of rest."

CHAPTER TEN: EGYPT

In the summer of 1936, immediately after our work in Cyprus, we sailed for Egypt. We came at the invitation of Mr. Joseph C. Carter, who was in charge of a Rockefeller Foundation station established in Cairo for the study of *Bilharzia*, the parasite transmitted to man by certain snails common in some parts of Egypt. I was accompanied during most of my stay in Egypt by Dr. J. B. Rice, my colleague in the anti-malaria work in Macedonia. Our stay was relatively short, from August to January, but long enough to give us some experience with an Egyptian summer; in August it was occasionally ninety-five degrees Fahrenheit in the laboratory but very endurable out-of-doors. The autumn was moderate and the winter pleasant, except when it rained too much, as it sometimes did near the coast. All weathers, warm or cool, seemed to suit the anopheles perfectly: they did not cease their activities during the hot summer or the mild winter.

We did our work in three parts of Egypt, the Valley of the Nile, the Suez Canal Zone, and the Oasis of Siwa—the last situated in the Sahara Desert far to the west of the Nile.

In the Nile Valley we found malaria widely distributed; scarcely a village but had some cases, and there was a fairly high incidence of the disease near rice fields and in the vicinity of certain large fresh or brackish lakes. On the whole, however, malaria was far less prevalent than in Macedonia or Cyprus. We did most of our work in the Delta of the Nile—that is, the part of the valley lying between Cairo and the Mediterranean. Here large dams are constructed in order to raise the level of the river so that its waters may be made to flow into a system of irrigating canals and ditches. These dams, some of which are also found in the upper reaches of the river, permit the irrigation of much larger areas of land than could be served by the annual rise of the river alone. This spread of fresh water allows extensive breeding places for anopheline mosquitoes and accounts for the prevalence of malaria.

There was a "good" Nile in 1936; at least it rose steadily and to sufficient height to fill the canals. I used to visit it almost every morning to see how much it had gained; it made about one step a day as measured by a stairway leading down to a wharf, a very convenient Nilometer. The river was honored that year with its annual celebration. A long procession of richly beflagged boats rode along the stream, cannons were fired once a minute, and there was the usual offering of a damsel to the river god—not a real damsel, but a dummy, stuffed perhaps with straw of last year's harvest. In former times, it is said, a real girl was thrown in. If she swam out, signs were that the river god was displeased, but if she sank, it was thought a good match. A dummy could be weighted and made to sink; doubtless Father Nile was always willing to accept a proxy.

The rise of that year was certainly enough to breed a myriad of malaria-carrying mosquitoes. The rising water seeped out from the canals, forming temporary springs and filling innumerable pools, so that the water in parts of that rainless countryside was almost as abundant as in West Africa during the wet season. The large canals did not breed many mosquitoes, perhaps because the water was so much disturbed by passing boats.

The relation of rice-growing to malaria was very different from that of the Philippines or Malaya, for in Egypt the rice fields harbor a dangerous vector of malaria. Rice is a favored crop there because it endures a "salted" soil better than do many cultivated plants. We could not confirm the theory, a favorite one several years ago, that the cultivation of clover was the cause of the "absence of malaria in Egypt," the assumption being that the anopheles were either diverted to the clover blossoms, as the Italian mosquitoes were to the pigs, or that the honey of the clover in some way prevents the formation of malaria oöcysts in the insect. We found that the Egyptian clover usually flowered in the winter after the peak of the malaria season, and, besides, there was no need of accounting for the absence of malaria in Egypt; there was plenty of it. Nevertheless the clover theory attracted much attention all over the world. It is a curious thing

in human nature that a mare's egg of plaster of Paris will, if large enough and attractively labeled and tinted, cause more admiration and comment than a truck-load of genuine hen eggs.

Several species of anopheles breed in Egyptian waters. Undoubtedly more than one of these are responsible for carrying malaria; but, as indicated by our tests, *Anopheles pharoensis* was the chief vector in the Nile Valley. It is a large, beautifully marked mosquito, capable of long flight, at least capable of flying aboard steamers passing through the canal. *Pharoensis* is an old acquaintance of ours; we used to find it in Nigeria occasionally, sometimes infected with malaria. We often found it infected in Egypt, where it was abundant in dwellings and stables. Among dwellings I include tents, which in that dry climate are almost as serviceable as houses of a more permanent kind, although the villagers prefer houses of mud or other cheap material. Curiously, *pharoensis* preferred tents for a daytime resting place; in them we most often found it, maybe because a large gray mosquito is more conspicuous on a canvas than on a mud background.

It was in Egypt that I first got the idea of using a white umbrella for collecting anopheles in houses and stables. The technique is simple: one raises the umbrella indoors and holds it upside-down against a thatched ceiling or in a dark corner of a bedroom, where the adult anopheles often lurk during the daytime. The surface above the umbrella was then sprayed with a pyrethrum spray. The dead or stupefied mosquitoes fell into the umbrella, where they were very conspicuous against the white background and could be easily collected. The umbrella handle was in the way for work close to the ceiling, and had to be cut off; but we found that if one amputates it below the catch, the umbrella can still be easily raised or lowered.

We wished to get a variety of such umbrellas; so we sought an Egyptian umbrella maker who supplied us with several types. Wishing to see if I could detect a sense of desert humor in Cairo, I asked the umbrella maker if many of his customers wanted their umbrellas upside-down. "No," he answered without a smile, "only doctors."

Just as in Malaya, we found a hospital one of our best collecting places for anophelines. In Egypt we made much use of an isolation hospital for infectious diseases, which consisted of a small village of canvas—an excellent material for the purpose because cool and easily kept clean. *Anopheles pharoensis* had a habit of entering these tents, biting patients, then collecting on the canvas ceilings, where the mosquitoes were easily captured. It happened that in one tent five people, all carriers of the gametocytes of *falciparum* malaria, were quartered awaiting diagnosis. We came there one morning and collected many specimens of *pharoensis* engorged with blood, which we confined in cages for a few days and then dissected. A very large proportion, over one-half, proved to be infected with malaria. Had so many infected mosquitoes assembled in this tent every day and been allowed to go loose in the neighborhood, they might have caused a considerable epidemic of malaria; as it was, the five patients were promptly treated for malaria.

We tested stomach meals of many *pharoensis* mosquitoes collected in this hospital and found that a high percentage of them consisted of human blood. That might be expected where so many human beings and so few domestic animals were housed; but we also found a fair percentage of human blood among stomach bloods of *pharoensis* collected outside of this hospital.

We began work in the Suez Canal Zone at Ismailia, a city notable in the history of malaria as the first place where the disease was controlled by anti-mosquito measures. We made no extensive surveys in the city itself—it probably contained little malaria —but we found plenty along the Suez Canal in the vicinity. The canal itself contains sea water, unfit for anopheline breeding; but there is plenty of fresh water in the Zone, brought in from the Nile by an irrigating canal traversing the desert. Water seeping from this canal formed abundant pools and even large ponds, very suitable breeding places for anopheles. We surveyed two villages for malaria. In Wasfiah, the school children showed a parasite index of fifty-nine percent and a spleen index of fifty; in Ezbet Serapeum, we found about the same indexes.

We found *Plasmodium malariae* (quartan) in the Suez Zone, two cases of it. This was an interesting find, because it was lacking in our surveys in the Nile Valley. *Anopheles pharoensis* appeared in the Zone, and we found one specimen malaria-infected. We also found *Anopheles sergenti*. Probably both species carry malaria in that locality.

The Suez Canal is very impressive to one traversing it by steamer. We passed along it during World War I, when we were on our way to Malaya. The British authorities had piled sandbags around the pilothouse as a protection against the snipers hidden along the bank; but no enemy came aboard the vessel except a bold *Anopheles pharoensis*, the first we had ever seen. I think this canal is even more impressive when seen from land. When riding by in an automobile along a desert road, one sees looming before him a huge ocean steamer—it is like meeting a whale in the Kansas prairies.

Of the three localities of Egypt we visited, the most interesting was the oasis of Siwa in the Western Desert close by the Libyan frontier. One travels by train from Alexandria to Mersa Matruh, passing along the Mediterranean and through Alamein and other places famous in ancient history and in that of yesterday. We did little sight-seeing on the day of our trip, for a desert dust storm obscured much of the landscape. From Mersa Matruh one travels the two hundred miles through the Sahara Desert to Siwa by automobile.

In the vicinity of the sea, the country is hardly desert. Bushy vegetation covers much of the ground and at the time of our visit (in November), herds of domestic animals were feeding there near some fairly large ponds. These were very disappointing: we were expecting to see desert mirages, and here were real ponds with animals drinking real water in them. The country along the sea has long been cultivated; it once was a part of the important Roman province of Cyrenaica.

As one gets deeper into the Sahara, the country becomes more desert-like. Domestic animals find little to feed on, and among large wild animals chiefly gazelles inhabit this region. I believe

these are hunted, illegally, by automobile, for a car ahead of us was hiding something which proved to be a captured gazelle. The road was fairly good, especially near the desert reservoirs, where one usually finds a patch of smooth hard ground, which serves as a sort of watershed to catch the water of the brief showers. The road and resting places along the route had been recently improved in preparation for a trip of the King of Egypt to Siwa—the only malaria journey we ever took where the pathway had been smoothed by kings. The King of Egypt was not the first royal personage who had followed that trail. Alexander the Great once visited the Siwa Oasis to consult the famous oracle of Ammon there.

The road was at least passable, for we reached Siwa on the afternoon of the same day—probably in rather better time than Alexander made. At the approach to Siwa the road descends steeply, for this oasis lies in a great depression many feet below the level of the sea. A strange-looking region: great mushroom-shaped rocks, their bottoms fashioned into a stem by the wind-blown sand, and hills high and pointed like some work of ancient man. One of them is indeed covered by the work of human hands, the buildings of the town of Siwa. Once the dwellings there were grouped so closely on the steep hillside that one's next-door neighbor might literally drop in on him. This piling up of residences has been discontinued because too dangerous. Since there is plenty of building room in this vast desert, possibly the ancient houses were thus thickly assembled for purposes of defense; or, it may be, the use of one's floor for the neighbor's roof might be an economy in building material. There was little wood to build with except the trunks of the date palm.

The water in this oasis boils up from large springs, some fresh and some brackish, and is said to come underground from the Nile. That great river, not content with dominating its own valley and invading the Suez Zone, must also thrust its wet fingers into the affairs of oases hundreds of miles away! The water from these springs is conducted by canals throughout the whole oasis, watering the soil over an area many square miles in extent. Little

is grown there except the date palm, almost the only source of wealth in the oasis. It affords dates for the people and for export, and the trunks serve as building material. The dates were as plentiful as peaches during a good peach year in Kansas; one could collect freely provided he ate them in the orchard and did not carry them away.

It is in the ditches that the anopheles are bred. The waste water flows into large shallow lakes, but this lake water is too briny for much animal life. In Siwa itself there were comparatively few anopheles to be found, for the ditches were kept clean and supplied with larva-eating minnows. We found a parasite index of only twenty-two percent among the village children and a very low spleen rate. We have here one example of the efficacy of a simple and inexpensive anti-malaria measure.

In another part of the oasis, about twelve miles away from the town of Siwa, the ditches were not kept free from algae and other debris, and larvae could grow in spite of fish. We visited a group of Bedouin tent dwellers there, two tents full of people of all ages and full of anopheles too—the ceiling of the tent was covered with them. We examined twenty-three children, all we could find, for blood parasites and enlarged spleen. Every single one had malaria parasites in the blood, and all had enlarged spleen except one little Ethiopian, who may have acquired some malaria tolerance from his Negro ancestry.

The mosquitoes proved to be mostly *Anopheles sergenti*, and were probably the chief carriers in the oasis. We found only one *pharoensis* in the whole region.

Larvae of *Anopheles multicolor* were abundant in the immediate vicinity of the Bedouin tents, but very few adults of that species appeared in the collections made in the tent dwellings. The breeding place of the *multicolor* larva was very remarkable for its high salt content. The larvae were found near a salt lake in small spring-fed pools, in which the water was so briny that the sides of the pools were literally encrusted with mineral glaze, resembling ice in a winter pool formed in an animal track. An analysis of the pool water showed a salt content nearly twice that

of sea water. Possibly the larvae spent most of their time at the surface of these spring-fed pools, where the water may have been less salty.

A remarkable thing, this high incidence of malaria in a nearly rainless oasis in the midst of the desert. The air is very dry there, but evidently desert species of mosquito, like desert plants, can adapt themselves to surroundings in which a jungle species would quickly perish.

One wonders how mosquitoes ever got into an oasis over hundreds of miles of desert—too far, it would seem, for the boldest flight. Probably an "eggy" female stowed away in some caravan and traveled by camel. On arrival she would have no trouble in finding suitable water to breed in. And it is no problem to account for the presence of malaria parasites in the remotest oasis. Possibly even Alexander of Greece, or some member of his entourage, carried a supply in his veins ready to infect the first mosquito vector which bit, and probably numerous malaria-carrying merchants had long preceded his visit—we know that the desert peoples of southern Arabia are no strangers to malaria.

And no one dreamed of the connection of mosquitoes and malaria. One thinks that a wise oracle would have dropped a hint, but oracles seemed to have concerned themselves more with the family affairs of kings than with the health of the people. With our present knowledge, it ought to be easy to control malaria in such a limited area, even if not so limited as in the sort of oasis we read about in many desert stories—a spring, a clump of palms, and a tent or two. But even in an oasis as large as Siwa, extending over many square miles, it should be possible to eradicate the anopheles or at least to protect the people effectively.

We found the villagers in Egypt very willing to coöperate in our surveys. They were quite ready to give a drop of blood or to allow the spleen to be examined, especially in villages where we had made one visit and got acquainted with the people. They understood that we were trying to do something for them, and were ready to congregate in the public room of the community, bringing children on foot and infants in arms, just as people had

done in Greece. A common sight was that of infants much emaciated by dysentery—"withered babies" we called them. The Eyptian doctors who accompanied us said that there was no hope of recovery for many of these. How these people would benefit by a little knowledge regarding the value to their babies of proper food and clean surroundings!

Once we visited a village without notice, a place in the region annually inundated by the Nile. We quietly set up our cot for spleen examination in the village public house and waited for the patients to come. They came very slowly at first, and the children made a great outcry when their fingers were pricked and when they were laid on their backs for spleen examination. But once examined, they thought it great fun to drag in other children just to hear them howl. These quickly dried their tears and became missionaries for more children; so finally we got a very considerable number of converts.

Another village, situated in the vicinity of a large date-palm grove, was particularly interesting from the malariologist's point of view. We picked up an assistant there to carry our larva-collecting tools—a volunteer, but, as it proved, one of the sort who expect to be paid for their labor. He was worth the money, for he had several wives and families whom we were allowed to examine for malaria, thus getting a start among the people of the village. A shame, though, that a man rich enough to afford more than one wife should not be willing to do without charge a little health work in his own village!

We once visited a large farm which we proposed to survey for malaria, but we were told by the manager of the farm that it belonged to a princess of the blood. Would we come the next day, after he had got the princess' consent? That we did, of course, and were amply repaid, for we found so many people lined up for examination that we could not examine all of them in one visit. But the princess asked no pay for her help!

We found another ally where we least expected it, the Koran. As everyone knows who has examined children's spleens, it is sometimes difficult to get a nervous child to relax the abdominal

muscles sufficiently to allow a palpation of the organ. One tries to divert the mind of the child to something other than his spleen; and one day we hit on the idea of asking a small boy to recite texts of the Koran. He was glad to show off a bit and soon forgot all about his belly. Once we examined a blind child who knew so much of the book that he had to be stopped when the examination was done, else he might have gone on for hours. I wonder if this was the first time that Islamism was invoked to help diagnose splenomegaly.

Egypt was for many centuries a land difficult for human enemies to penetrate, so encompassed it was by wide deserts; and up to very recent times it has been equally difficult for anopheline invaders. Now the barriers are less formidable for both sorts of enemy. It is said that *gambiae* has reached some points in the Nile Valley by airplane from Ethiopia or the Sudan, and it is possible that *elutus* may eventually arrive from the north.

Like human invaders, the mosquitoes are likely to find a place in Egypt to colonize once they get in. I have seen cesspools in villages of the Nile Valley which should be as favorable for *gambiae* as are the street pools of Lagos in Western Africa. *Anopheles multicolor,* fortunately not a particularly dangerous species, is already plentiful in these Egyptian pools, and would probably welcome a neighbor. Pools and ponds in the Suez Canal Zone, or those in some brackish oasis, might harbor *elutus,* if it ever gets passage to them. *Pharoensis* is said to be primarily an Ethiopian species, which has worked its way from the south and obtained a foothold in Egypt. We should be ever on our guard against the introduction of these more dangerous mosquitoes to Egypt and be ready to stamp out any invaders which may succeed in colonizing there.

CHAPTER ELEVEN: INDIA

India is a land famous in the history of malaria. It was there that Ronald Ross made the fundamental discovery that anopheline mosquitoes transmit malaria, and the British Indian Medical Service, through a century or more, has made important additions to our knowledge of infectious disease. In view of those Himalayan contributions to knowledge our brief malaria research seems hardly worth mentioning.

Our stay in India was comparatively short, from January to November, 1937. We did our work in Poona, situated in the Bombay Presidency about 120 miles from the city of Bombay. Poona is the site of the celebrated Observatory, a meteorological institution, which, Mark Twain notwithstanding, has done a great deal about the weather. It has furnished much information valuable to agriculture and war, as well as to the mountain climbers who from time to time have attempted the conquest of Mount Everest in the Himalayas. Mountaineers want to know when to expect the arrival of the annual monsoon, which clouds the high peaks; and the Observatory is called on to furnish the earliest information as to its coming.

At the time of our visit the monsoon changed in June. This change was a rather disappointing affair to me, for I had expected that the wind would shift suddenly and begin blowing from the opposite direction, bringing some dramatic change in weather. The weather did change from very hot to cool and cloudy, but rather gradually, and the wind shifted only a few degrees. I could measure its change by the smoke from a neighbor's chimney, which was particularly foul-smelling; at one phase of the monsoon it entered my hotel and at another fortunately missed me by a few points of the compass.

The rainfall in the region of Poona is curiously variable. At Paud, about fifteen miles from the city, it is nearly sixty inches per year, while at Poona itself it is only twenty-seven inches. There is enough in the Poona area to support two sizable rivers,

which bear the musical names of the Mutha and the Moola. These join within the urban area of Poona and the combined rivers are known as the Mutha-Moola; very decent of Moola to take second place after the hyphen, for, I believe, it is considerably the larger stream. If we in America were to name the river below the juncture of the Mississippi and the Missouri by a similar hyphenated name, I wonder which river would be willing to yield the first place.

We arrived at Poona during the dry season when the flow of these rivers was comparatively small, and their broad beds contained streamlets and pools very convenient for collecting anopheline larvae. When the monsoon changed and heavy rains fell, the rivers became broad torrents filled from bank to bank.

Malaria was abundant in many parts of the Poona area, especially where irrigating ditches, natural streams, or swampy ground furnished the water necessary for mosquito breeding. The chief health officer of the district told us that the medical officers did not consider a village with a parasite index of less than twenty-five really malarious. We found among children in the rural irrigated regions parasite indexes as high as seventy-one and spleen indexes up to one hundred. The general average of malaria prevalence in the country around Poona was far below seventy and lower than that which we had found in Cyprus or West Africa. In the city of Poona the malaria index was much lower than in rural districts, as is commonly the case in large towns. Near the rivers it was somewhat higher, but at a distance of one-half mile away from them it was almost nil. In the country, anophelines easily disperse a distance of half a mile; but in a city, the numerous inhabitants en route may deflect the flight of the majority of blood-seeking mosquitoes.

We had excellent assistance from the local health officers, and it was owing to this aid that we were able to examine spleens and bloods of nearly twenty-five rural villages during a comparatively short stay. The chief health officer sent a message to the villages we proposed to examine, asking the people to have the children ready on our arrival; so we usually found them lined up on the

roadside or in the village public house. A cot for the spleen examination and an interpreter to register the names of the children were all we needed, and we could do several villages in a day. The people, as everywhere, were willing to help, for our work was for their benefit; though I imagine that sometimes they thought that the benefit was slow in coming.

The native villagers of this region struck me as a rather frail people physically. This condition was probably due in part to malaria, but undernourishment was undoubtedly another factor. As in so many countries I have visited, the lack, or poor seasonal distribution, of rainfall affords the main obstacle to abundant agriculture. The government of India has impounded some of the larger rivers of that region, and furnished much irrigation and electrical power. Irrigation here works in two ways; it adds to the supply of malaria as well as to that of food. We found a blood parasite index of nearly forty percent in rural irrigated villages of this region, and only a little over ten percent in the non-irrigated. Proper anti-malaria measures may eventually correct this evil, so that irrigation will afford a less doubtful advantage.

I was struck by the large proportion of quartan among the malaria parasites we found in India. In most countries where we made surveys, it is present in relatively small percentage. In the Nile Valley we found not one case and in the Suez Canal Zone and in the Siwa Oasis we picked up a very few; but in the Poona region of India, we found *quartana*, *vivax*, and *falciparum* in about equal quantity.

The anopheline fauna of India is a very rich one; we identified seventeen species in the vicinity of Poona. Of these, the most abundant and the most important in malaria is *Anopheles culicifacies*. It was the commonest species in the rivers of Poona, and could be found in clear springs, pools, wells, and ditches, but was little disposed to breed in water highly contaminated with organic material.

We found India a most interesting region for the study of anopheles and malaria. The species of mosquito were abundant, and their breeding places were varied and numerous. The an-

opheline larvae were very adaptable to breeding waters; we found five different species on one occasion, all within an area of five yards' radius. On that same trip, we found a species of anopheles in a buffalo wallow; both mosquito and buffalo are somewhat different from those Dr. Hertzler reports from the prairies of Kansas. In our study of anophelines we found very convenient the extensive publications of the Indian Medical Service, especially their excellent manuals for the identification of mosquito species.

We dissected a large number of adult anopheles, but found sporozoites in only one species—*culicifacies*—and that in only three-tenths of one percent. Contrast this percentage with that we found in *gambiae* in Africa, six and one-half, or that in *superpictus* in Cyprus, seven and one-half percent. The malaria indexes were not very high in the Indian localities where we collected mosquitoes for dissection, but there was enough to show that a low sporozoite index might account for considerable malaria. Our surveys were limited in time and locality, and it is quite possible that a higher sporozoite index might be obtained in another locality of the Poona area or in other years.

Culicifacies had also the highest incidence of human positive among stomach bloods, all of which we tested by the precipitin method. In this estimate we reckon only those species of which we found a significant number of blood-engorged, about two hundred.

In the Poona region of India cattle and man are often housed under the same roof. We made many of our collections in rooms adjoining courtyards which sheltered both man and domestic animals; thus the mosquitoes had a fair choice of hosts. Our serums for the precipitin tests were sent from Italy in the dried form, and served very well when dissolved in saline before use.

We found over two hundred blood-engorged specimens of *Anopheles subpictus*, the most of them collected in rooms adjoining courtyards, or (in over twenty-five specimens) in rooms housing only man at night; but we found only one specimen containing human blood. *Subpictus*, it may be remembered, was the species frequently found in the Philippines in localities where

there was no evidence of a transmission of malaria. It usually bred in the rice fields there; and in many countries of the Orient, as Malaya, it is common in foul waters near the habitations of man. It was *subpictus* that we found in the wallows of buffaloes, a common domestic animal in India.

In the vicinity of Poona we found only a few of *Anopheles stephensi*, a species known to be a formidable vector of malaria in Bombay and in other parts of India. It is remarkable for its ability to breed in water very shallow and containing a sparse amount of organic material. It is reported as thriving during the rains on cement roofs in cities, very conveniently for the mosquito but far less so for the malariologist, who might have to enlist the services of a fire company to control malaria. I have noted mosquitoes breeding in waste water high up in a New York hotel, but fortunately *Anopheles stephensi* does not occur in this hemisphere.

The anopheles of India are indeed very adaptive as regards breeding places, for they are found not only on roofs but in deep wells. The wells in the Poona area contain the larvae of a considerable variety of anopheles; we found nine species there. The majority of the Indian wells were much more accessible to mosquitoes than ours in America. They were rather pits than wells, the commonest type being about eighteen feet in diameter, twenty or thirty feet in depth, and open to the air and sun. We found an interesting type near a Parsee temple, where the wells were used only for religious purposes. The Parsees, of whom there are many in the Bombay Presidency, believe that fire, water, and earth are sacred, and for that reason they do not allow the human dead to pollute any of these elements but expose them to vultures in the famous "Towers of Silence." In one temple, the priests told us, were altars on which the sacred fire remained unextinguished for two hundred years.

But the wells in the Poona area seemed never to breed a sufficient number of anopheles to affect greatly the incidence of malaria. In a certain suburb of Poona where wells were abundant, the malaria index was almost nil.

Through the courtesy of Dr. Jacocks, Director of The Rockefeller Foundation in India, and of various members of the British Indian Medical Service, we were enabled to take many longer trips within India, all the way from the forests in the south to the Himalayas and east to Assam and Ceylon. I was surprised to see so much wilderness in southern India, considering that it has been inhabited by civilized man since the dawn of history; there seemed to be literally hundreds of miles of woods and plain with only an occasional village. We had no opportunity to survey these villages; they are said to be highly malarious. Indeed malaria is given as one of the chief reasons for the vacant lands in India. Of course some areas, apparently wilderness, were in part devoted to teak-wood cultivation, and may not have been so wild as they seemed. But the wild animals did not mind whether the woods were primitive or artificial, if one might judge from the large numbers of them everywhere visible. Along the road we often encountered deer, wild fowl, and monkeys, and once what the chauffeur said was a young tiger. We were told that the number of wild animals had increased since the end of World War I, probably because many of the hunters had been occupied with human wars and had not had the time to hunt wild beasts. We came to one village recently visited by a man-eating tiger, which had carried away two children; but we saw nothing on that day more terrifying than panther tracks.

We saw the Himalayas in the wintertime, when the wide horizon was covered by snow peaks. The geologists tell us that the Himalayas are comparatively recent—upstarts literally in the history of the world. In traveling to these mountains, we crossed a range of lesser height which had reached a respectable age when the Himalayas were born.

In Ceylon we saw the region where the extensive malaria epidemic of 1934-35 occurred—one of the most notable epidemics in all the history of medicine. About the middle of the 1930's, the southwest monsoon failed, and then the northeast monsoon did likewise; so that there was a great drought in a part of the island. Certain large rivers, which ordinarily flow with a deep, wide cur-

rent, were reduced to a chain of pools or dribbling streams containing clear water in their sandy or stony beds. This kind of water formed an excellent breeding place for *Anopheles culicifacies*, the adults of which began to swarm in the villages. There was already enough malaria to give the epidemic a start, and soon the hospitals were filled. This situation contrasts with that of Macedonia, where rains, especially those of summer, usually cause a great increase in malaria. In both cases, the breeding places of the more dangerous anopheles are increased, but in different ways.

Ceylon contains numerous remains of an ancient civilization, indicating a former population far more abundant than that of today. It has been suggested that malaria had a large part in causing this decrease, perhaps a succession of epidemics like the one we have just described. Others think that the old civilization was destroyed by invaders from the mainland of India, an explanation which seems to me the more probable one. A nation gets accustomed to an endemic disease, even if sorely crippled by it; but a sudden devastating human invasion may in a few weeks overthrow the work of centuries.

In Assam we visited the tea gardens where malaria is controlled by shading the breeding places of *Anopheles minimus*, an anti-malaria measure described in my chapter on Malaya. Hillside rice fields are a source of *minimus* in that country, a hazard difficult to deal with by shading. The rice fields are in part watered by flowing streams forming an excellent breeding ground for *minimus*. We find a similar state of things in many terraced rice fields in various parts of tropical Asia.

Assam was once the seat of a higher civilization. According to one account its decline was due, not to malaria, but to the importation of opium from China.

The region in the vicinity of Calcutta, the second largest city of the British Empire, was especially interesting for the malariologist. The malaria in one part of the city was then being increased by the health activities of man; a large conduit had been constructed to carry the sewage of the city to a huge lagoon,

formerly too salty to produce many anopheles but now, through the flow of drainage water, becoming fresh enough to breed anopheles. Doubtless this fault has long since been corrected.

We saw, too, the extensive anti-malaria projects in the vicinity of New Delhi, where drainage and filling were chiefly used to cope with malaria in and about that city.

I visited the neighborhood of Calcutta with a guide familiar with the malaria of the region. We saw a ridge formed by an ancient channel of the Ganges, on which the terrain is different from that of the rest of the plain and produces more vectors of malaria than do the other parts of the country. The ridge was doubtless formed by centuries of flood, which deposited the heavier silt near the channel of the stream until the river was literally lifted—as by some giant machine—above the level of the plain. We see how the banks of the Mississippi, and of many great rivers traversing a plain, are often well above the surrounding valley. The ridge which we saw near Calcutta may be very ancient, for the Ganges now joins the Brahmaputra many miles to the north.

The relations of rivers to malaria is a most interesting one: We have seen how the great rivers of Ceylon may become dangerous through drought, while still remaining in their channels; and we shall see in the chapter on Brazil how the same thing occurs there. Other great rivers may be nearly harmless until they change their courses; then they leave behind them dangerous malaria breeding places, like the "oxbow lakes" common in the Mississippi Valley or like the ridges of the Ganges.

CHAPTER TWELVE: BRAZIL

In 1939, when I was age-retired from The Rockefeller Foundation, I did not dream that the most interesting and perhaps the most important malaria experience still lay before me.

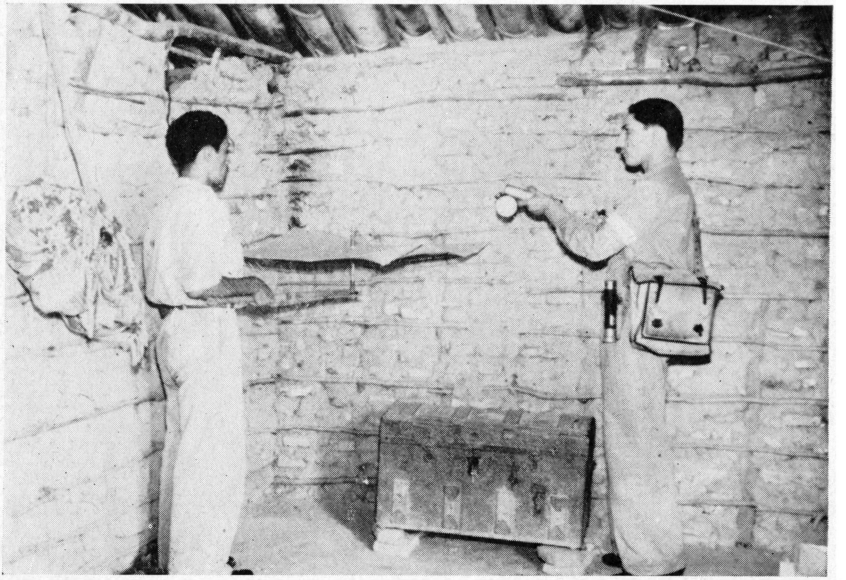
Having decided to forego retirement, I planned a malaria trip "on my own"; the most of it to parts of the world I had not yet visited. I took a plane at Miami, Florida, for Santiago de Chile, descending for brief overnight stops at the Canal Zone; Guayaquil, Ecuador; and Arica, Chile. Each of these three localities is, or has been, a notorious center of malaria—the first two for yellow fever also. Arica is one of the very few places in Chile where malaria is known. In an irrigated valley there, my old New Mexican associate, *Anopheles pseudopunctipennis*, was causing some trouble. This species, or some variety of it, is carrying much malaria in localities along the Pacific side of South America, especially in parts of Peru where irrigation permits of its breeding.

In Santiago there is no malaria; probably because, as in the Fijis, there are no anopheles to carry it; or if they ever occur there, they are not numerous enough to cause any serious malaria problem. Through the courtesy of the health authorities of Santiago, I visited some streams which certainly were good places for anopheles if any were present in the country. The water was clear, and its surface was partly covered with floating vegetation, not enough to render the water too foul for anopheles but quite sufficient to afford them protection and ample nourishment. I dipped this place thoroughly, but found not one anopheline larva, although I easily found culicine larvae close by. Chile is not wholly surrounded by the sea as Fiji is, but it certainly does not lack barriers sufficient to deter the boldest anopheline pioneers. All along the west is the Pacific Ocean; the north is barred by almost limitless deserts, the east by the Andes, and the south by the polar cold. One gets a good view of three of these barriers when traveling by plane from the north—the Andes on the left,

Near the Malaria Institute, Adana, Turkey: Dr. Barber (center) with Dr. Mahmud and Miss Bedia

A Village near Adana, Turkey

A Brazilian Distributor of Antimalarial Drugs
By courtesy of The Rockefeller Foundation



Using a Square Umbrella to Collect Mosquitoes
By courtesy of The Rockefeller Foundation

the brown plains beneath, and the rolling Pacific surf on the right.

I crossed the Andes without benefit of artificial oxygen, and in a few hours arrived in Buenos Aires. Argentina is also nearly malaria-free, a fact suggesting that there is something besides mountain or ocean barriers to protect these southern countries. In one area, in northern Argentina near the Ecuadorian boundary, there is considerable *pseudopunctipennis*-borne malaria. The Argentine health authorities enabled me to visit this area, so that I visited some interesting malaria ground as well as an interesting country. Possibly Argentina owes its comparative freedom from malaria to the absence of highly effective mosquito vectors, a good argument for the thorough "de-anophelizing" of airplanes. Inland travel, except along certain large rivers, was difficult in South America before the arrival of air transportation; possibly one reason for the fewness in the south of those undesirable tourists—disease-carrying mosquitoes.

In Buenos Aires I was met by an old friend, Dr. Fred L. Soper of The Rockefeller Foundation, then in charge of the Foundation's work in yellow fever and malaria in South America. Dr. Soper invited me to go with him to Brazil, where there had been considerable trouble with malaria. Glad to accept this offer, I immediately proceeded to Brazil, where I worked during the greater part of the summer of 1939. The anti-malaria work there was in the immediate charge of Dr. Soper and his colleague, Dr. D. B. Wilson; and from them I obtained much assistance in all phases of my work. It is to these workers that credit is due for the extirpation of *Anopheles gambiae* in Brazil, one of the greatest accomplishments in all malariology.[1]

The history of the invasion by *Anopheles gambiae* begins in 1930, with the discovery by Mr. Raymond Shannon, entomologist of the Foundation, of a small area at Natal, Brazil, infested by *Anopheles gambiae*, which Mr. Shannon early determined was the same *gambiae* as that long known in Equatorial Africa.

[1] For much information relative to *gambiae* in Brazil, especially in regard to what happened before and after my visit, I am indebted to Soper and Wilson, *Anopheles Gambiae in Brazil, 1930 to 1940*, The Rockefeller Foundation, New York, 1943.

A fast mail service had recently been established between Brazil and Dakar, West Africa, and it is practically certain that the mosquito had been carried across the Atlantic by an airplane or swift destroyer, more probably the latter. Natal is on the nose of South America where it points eastward to West Africa, and the distance from Natal to Dakar is a little less than two thousand miles, a voyage which was then being accomplished by fast destroyers in less than a hundred hours. Possibly a single *gambiae* full of eggs made that fateful voyage. How much suffering and death could have been avoided, and how many millions of treasure saved by one de-infestation of that vessel—possibly by a single whiff of an insecticidal spray!

The first evil fruits of this invasion were not long delayed. In 1930, when the *gambiae*-infested area was restricted to a small patch of a few square kilometers, a severe epidemic of malaria broke out in the vicinity of the landing place of the invader. Almost one hundred percent of the people in that area were stricken, and the deaths were so numerous that it was rumored that yellow fever had reappeared. So many were incapacitated that the authorities had to furnish food as well as medicine to the population. The *gambiae*-infected zone steadily grew, and in January, 1931, came a second malaria epidemic much worse than the first. In a certain workers' suburb, 10,000 cases were reported in a population of only 12,000 persons. And all this malaria was due, not to the introduction of any new African malaria parasite, but only of a particularily efficient mosquito vector!

Malaria was present in that part of Brazil before the arrival of *gambiae*, but it had rarely attained epidemic or even highly endemic proportions, probably because the native anopheles were poor carriers of malaria. So when *gambiae* set foot in that region, it found a people with little resistance to the disease. They were in much the same position as New Englanders would be if they should attempt to colonize in Liberia without screens, sprays, drugs, or any other protection against malaria.

Early in March of that year, the Brazilian Ministry of Health and The Rockefeller Foundation began anti-mosquito measures

consisting of Paris-green dusting. This work was continued by the Brazilian Health Service during the year, and *gambiae* and epidemic malaria disappeared from Natal and its vicinity. In 1939, we surveyed a locality which had suffered from one of these epidemics; we found not a positive blood specimen, but only a moderate percentage of enlarged spleen—the dead embers, one might say, remaining after the great conflagration which had raged there nine years before.

Although *gambiae* had been practically stamped out in Natal, it had escaped to localities away from the coast, and its presence was made known by occasional epidemics, some of them of great severity. Then in 1932 came a severe drought, which persisted in greater or less degree throughout the two subsequent years. In that part of Brazil—including the states of Rio Grande do Norte and Ceará—a failure of the rains, which normally come in the period February to May, brings a major calamity to the people. Famine and pestilence prevail, and many persons take flight to better-watered localities. Then from 1932 to 1937 came what Soper and Wilson appropriately call "the Silent Era" of *gambiae*. The mosquito still lurked in the country and was stealthily extending its borders, but no explosive outbreak of malaria betrayed its presence. But in April and May, 1937, extensive epidemics of *gambiae*-transmitted malaria appeared in the valley of the Jaguaribe River in the state of Ceará, about two hundred miles as the crow or airplane flies from Natal. I state particularly "as the crow or airplane flies," not as the mosquito flies. The latter probably traveled more as nomad tribes did when they invaded Europe, colonizing and advancing from new centers; but the mosquitoes enjoyed modern advantages, and may have hitchhiked over parts of the distance by automobile, or embarked for short voyages in motor or sailing vessels cruising along the coast.

It is an interesting fact that *gambiae* traveled northeastward, instead of southward where it might have eventually entrenched itself in the valley of the great San Francisco River. It is stated, rightly, I think, that its flight was influenced by the southeast trade wind, which blows strongly during the greater part of the

year in that part of Brazil. Mosquitoes will fly diagonally against a moderate wind, like a tacking ship, but in a strong wind they are prone to hide in bushes or other shelter, and only if they venture out, might be carried by the wind. We once surveyed a stream situated south of Natal, and found not a *gambiae* larva, although it contained breeding water favorable for that species.

In the broad bed of the Jaguaribe, *gambiae* found a breeding place as much to its taste as that which *culicifacies* found in the rivers of Ceylon. In Brazil no unusual weather is necessary to prepare the river for anopheles. While the normal spring floods are on, the river is quite unfavorable for mosquito breeding; but in the dry season of summer and autumn it is reduced to a small stream, meandering in its sandy or gravelly bed. *Gambiae* larvae are found in this water, but more abundantly in the numerous clear pools scattered in the bed of the river. At the margin of stream or pool, the sand was often saturated with the seeping water; so that even the casual track of a child or goat may fill with water and become a prolific breeding place. During the dry season the river beds are frequently used as farms. Then ditches and the hollow places scooped out among the fields fill with water and become excellent sources of *gambiae*. These also invade the shallow, seepage-filled wells, commonly known as *caçimbas*, plentiful in the river bed and among the farms. It is bitter irony that wells, for centuries homely, harmless, necessary things, should suddenly become sources of death.

With the coming of the spring rains, farms, fences, and everything not rescued are swept out of the river bed, and the stream becomes a raging torrent, no longer habitable for any but a few of the hardiest larvae; a transformation similar to that produced by the full monsoon in Ceylon. But *gambiae* may continue its travels and depredations. The beds of ponds, sloughs, and various depressions along the valley above the river banks fill with rain water and *gambiae* may continue to flourish, as it did in the rain pools in Africa. These valley pools may persist far into the dry season; some of them are used as watering ponds for domestic animals, and with their bordering track pools become so

turbid that the water is fairly soupy with mud. Yet *gambiae* flourishes there as it does in the bright clear pools in the river bed. Only when ponds grow old and fill with algae and various aquatic plants do they become unfit for *gambiae*, although they are then still habitable for native anopheles.

The river-bed agriculture favors *gambiae* in another, less direct way. Farmhouses and villages are plentifully strung along the river bank convenient to the farms, and these offer abundant sources of human blood to the mosquito. Examining one of these houses near the river, one finds it swarming with adult *gambiae*, ready at nightfall to attack the people, to seek the river and deposit new batches of eggs, or to continue its journey along the valley.

The amount of sickness and death which followed *gambiae* into the valley of the Jaguaribe was almost unbelievable. Towns and farms were alike invaded. We visited one village where the people said that almost everyone was in mourning: usually it was worn for an elderly person or a child; the weaker suffered most, but no one had much resistance to the disease. Another village declared a public holiday and thanksgiving on the first day when death failed in his accustomed visits. People crowded the clinics, established for the treatment of the sick. Often there were not enough people well enough to seek food or medicines. They were even unable to carry their dead to the usual cemeteries, and had to bury them in improvised graves.

The doctors of the country had never seen an epidemic like this one; no wonder that at first they mistook it for yellow fever or some malady equally fatal. To the people, it was a new disease. On one trip we met a villager whose earnestness and solemn mien earned him the name of "the prophet of Limoceiro." The day we visited his village the epidemic had abated, but there were still sick persons in his household. He had but one eye, but evidently he had seen a good deal; for, coming to the door, he said, "This evil came on us last April. We had never known it before, *and it will never leave us.*" Thanks to the Brazilian government

and to The Rockefeller Foundation, this prophecy was not fulfilled.

My first headquarters in Brazil were at a laboratory in Aracatí, a town situated on the Jaguaribe near its mouth. It was formerly inhabited by wealthy Portuguese merchants; and, I was told, harbors many a piece of rich furniture stored away in its dwellings, a Golconda for antique hunters. There I made my first acquaintance with Brazilian hammocks, the universal sleeping furniture of that part of Brazil; "beds," "bedsteads," and "bedrooms" are terms long become obsolescent. All that is needed in a sleeping room is a couple of hooks for slinging your hammock and a blanket or two; with these one is ready for the night. One soon learns to sleep diagonally, not straight lengthwise, in the hammock, and to adjust the migratory blankets so that they will not slip out on the floor.

One wonders how the hammock custom became established in that country. I have my own theory. There is a certain large, fat toad which has learned to climb stairways and occasionally gets underfoot in a dark bathroom. I imagine these toads learned to climb bedsteads too, and hence the hammocks. Bed nets could be adjusted on these hammocks, and they were certainly useful, especially for me, for I slept with a window open, unmindful of the "night air" still dreaded in that country.

The town was full of malaria. There was a clinic for the treatment of the sick, but people told us they were too ill to go to it for medicine. *Gambiae* adults were plentiful in the houses, and larvae could be easily found in watering holes in the immediate vicinity. That was in May, 1939, before the anti-*gambiae* campaign had fully got under way.

In addition to screening, I also employed prophylactic treatment, the "suppressive" treatment mentioned in my chapter on the Philippine Islands. But here the malaria workers used atabrin in the dosage recommended by the Malaria Commission, two tablets (ten centigrams each) daily for three consecutive days followed by a rest period of six days. This treatment possibly saved me from malaria during my stay in Aracatí; anyhow it caused no

discomfort and did not turn me yellow as atabrin is said to do sometimes. At the worst, better be yellow than sorry.

My next laboratory was in Natal, the famous landing place of *gambiae*. There I was housed in a vacant wing of the maternity hospital, my hosts probably thinking I would feel quite at home among other newcomers to the country. Since the hospital was on a hilltop, and my room well up in the building, my most vivid remembrance of the place was of the trade wind, which blew strong and steady day after day and night after night. I also remember that I was given a real bed, but it was so desperately hard that I was glad to creep into my hammock.

We had a good working place there, and one of my tasks was to persuade the mayor of the town that Paris green, properly used, was harmless to man or domestic animals. I did this in a very simple way—just by putting a minimal dose lethal to anopheline larvae into a bowl of water, then drinking the water myself. The mayor was immediately satisfied; but, curiously, he never returned to see if the larvae died (which they did) or to see if I survived (which I did). I knew I was taking no risks, for a dose of this reagent large enough to kill mosquito larvae is quite harmless for man. In our laboratory at Natal, Paris green was being prepared in the basement, and enough was carried in the air to our laboratory upstairs to kill some of our larvae; yet we, who breathed the air every day, felt no harm.

Paris green was still in use in Natal, and *gambiae* larvae were certainly scarce in that region. We found none in Natal and but few in the vicinity—these far up in the bed of a river.

Aracatí was in the midst of the *gambiae*-infested region. My next station was on the *gambiae* frontier at Iguatú far up the Jaguaribe River. At that time we could speak of clean and *gambiae*-infested territory, and Iguatú was a few miles inside of the territory being traversed by the enemy on its upward march along the river.

For the malariologist this locality was full of interest. The river there was much as in its lower regions; with steep banks, scantily wooded, and a broad bed for its meandering stream,

which was crossed by numerous brushy fences dividing the river-bed farms. Along the shore was a string of farmhouses and villages. Far up the valley the stream-bed pools contained anopheles in abundance, but no *gambiae*. In the riverside houses there, we did not find an adult anopheline of any kind; the native mosquitoes do not have the house-haunting habit characteristic of *gambiae*, nor did the people have any malaria.

Then below the *gambiae* border, the river bed was full of *gambiae* larvae, and the houses swarmed with their adults. But still no malaria or perhaps a little in the clinic of Iguatú, probably brought in from long-infested localities. A few miles farther downstream, about five miles below Iguatú, epidemic malaria was in full blast. Here in a village, Genipapeiro, we found a blood parasite index of ninety-six percent. Nearly three out of five inhabitants were sick in bed or had just got up. The spleen index, always lagging after a sudden parasite infestation, was already up to twenty-two, but the mortality index was very low, nil or nearly so. There were two good reasons for this low death rate. The treatment squad employed by The Rockefeller Foundation and the Brazilian government had arrived on the scene promptly after the outbreak of the epidemic, and had dispensed atabrin to check the plague and preserve lives. A second reason is found in the species of parasite; in every single case we examined, and we took blood specimens of many persons, the parasite was *Plasmodium vivax*.

We can surmise what was going on: *Anopheles gambiae* was slowly passing up the river valley. Thousands of the mosquitoes were being bred in the stream and they were crowding the houses and feeding on the people. But no malaria appeared in the upper miles of the invasion, because the mosquitoes had not yet become infected. Then at Genipapeiro a good malaria carrier appeared, probably from a neighboring village or from the refugees fleeing before the oncoming plague, and within a few weeks he infected many *gambiae*, ready to spread malaria throughout the town. Genipapeiro was lucky in a way, for its malaria happened to be of

the less dangerous type. If a carrier of *falciparum* had come instead, the people of this village might have fared much worse.

Just across the Jaguaribe from Genipapeiro was another village which had worse luck. Malaria had but recently arrived, when we visited a certain house in the village where we found every member of the household, nine persons in all, lying in their hammocks desperately ill, and every person with the more dangerous *falciparum* parasites in his blood. Their condition was such that the first thing to do was to provide food, then remedies. After seeing an attack like this, one could believe the ghastly tales related of people on isolated farms; where, it is said, everyone died, being unable to get up and seek food or remedies.

I was told that owing to the activities of the anti-*gambiae* workers, malaria never got above Iguatú. It seems a miracle that the epidemic zone did not spread further up the river before the mosquitoes could be exterminated. One would think that a single refugee, loaded with malaria parasites, might spread the pestilence as a firebrand spreads a conflagration when blown into a tinder-dry forest.

We made surveys in the lakes which abounded in that vicinity, vegetation-filled, but apparently free from *gambiae;* indeed, we found hardly a *gambiae* beyond the vicinity of the river. We were there during the dry season; the mosquitoes were probably plentiful enough during the rains, but not in lakes. These, happily, did not harbor *gambiae,* else their extirpation from that region would have been nearly impossible.

Riverside farms were numerous along the main stream of the river as well as its branches. The high fences between the farms had to be surmounted, and we got expert at climbing them. Travel in the river beds except on foot was practically impossible, but foot travel was the more interesting, for one could get so close to things. The river there was reputed to be infested with *piranhas,* the Brazilian sharp-toothed fish said to attack man, especially persons who happened to have a taste of blood on the skin, caused perhaps by some chance scratch. We did much wading,

but never chanced to encounter one of these fish, probably because they sought deeper waters than did *gambiae*.

Iguatú was indeed a delightful place to live that summer. We had an excellent host, the mayor of the city, who was also the director of the hospital and the broadcaster of the region. And he gave us a fine laboratory, excellent food, and a real bed.

We found the Brazilian villagers as ready to aid as were those of Egypt or Macedonia. The houses were always open to us for our mosquito surveys, sleeping rooms and all. We often had to wriggle around in a hammock-filled bedroom, perhaps easier to penetrate than a room crowded with beds; certainly a baby hammock was easier to manage than a cradle. On the wall outside we sometimes found a bamboo cage full of honeybees, the stingless sort; one could hold them in the hollow of his hand, unscathed. Like the people themselves, these bees were gentle and kindly but not much given to the accumulation of worldly goods—honey or other wealth.

The only exception to our welcome was a rumored one. We were told that some people across the river from Iguatú were unwilling to have blood specimens taken, because, they said, there once dwelt among them a very holy man, who, before his death, which had occurred some time before, had prophesied that the world would soon come to an end and that a sign of the imminent catastrophe would be the arrival of persons, undoubtedly devils, going around taking drops of blood. We had no occasion to visit this village and it is a pity we did not, for it would have been a novel experience to be a portent, especially of such an interesting event.

In the state of Ceará we saw an illustration of the value of education in health matters. We asked if the people ever used screens. Some had never heard of them; others said that they knew of their use in the Amazon Valley or some other distant place. Yet these people had literally in their own hands a method of screening which might prevent much sickness or, at all events, might alleviate the mosquito biting which deprived them of comfort at night. And all that with little or no expense. The people

of that state are very clever at cloth weaving; we often saw the ladies of the household bending over a sort of cushion-like affair, on which they spread their needlework. The fabrics were sometimes of a light, open construction, which would do well enough to keep out *gambiae* without too much obstructing the movement of air. The villagers grow their own cotton and make their own thread. It is true that the tiled roofs of the houses are sometimes full of holes large enough to admit the hungry *gambiae*, but it would be quite possible to screen off the sleeping apartment, and eventually the whole house could be so constructed as to make mosquito-proofing more feasible. Screening is not so necessary now that *gambiae* is driven out, but one must be prepared for the return of this pest or the arrival of a new one.

We sometimes took long excursions in the bush to determine how far *gambiae* had spread into new territory—to survey the boundary of the clean and infested zones. We usually started in an automobile, sometimes through the brush where roads were lacking, sometimes skirting swamps and crossing crazy bridges; where, perhaps, no automobile had ever ventured before. On arrival at a farm or village, the first thing to do was to find out if *gambiae* had already moved into it. Waters were searched for the larvae, easily recognizable to the experienced eye. Even an uneducated assistant with sharp eyes can often make a useful preliminary identification, later to be confirmed in the laboratory.

Then the house, especially the sleeping rooms, had to be searched for the adult mosquito. For this purpose we made much use of the white, upside-down umbrella I have described in the chapter on Egypt. The Rockefeller Foundation workers have improved our model by making the umbrella perimeter square, so that the umbrella will fit into corners well. I wonder if my Cairo umbrella maker would have smiled if one of his doctor customers had wanted his umbrellas both upside-down and square.

The best place to search for *gambiae* was in dark corners, especially of a sleeping room. Female anopheles, after biting and becoming engorged with blood, usually seek a dark corner where they rest during the day. Males never seek blood but are often

found in the same hiding places, perhaps in greater proportion in *gambiae* than in certain other species, the males of which often hide in hollow trees or empty buildings. It was fortunate for us that the male *gambiae* stayed in shelters where they were easily caught, for they possess certain anatomical peculiarities which make the species easily recognizable, even in specimens crushed or bedraggled by the spray.

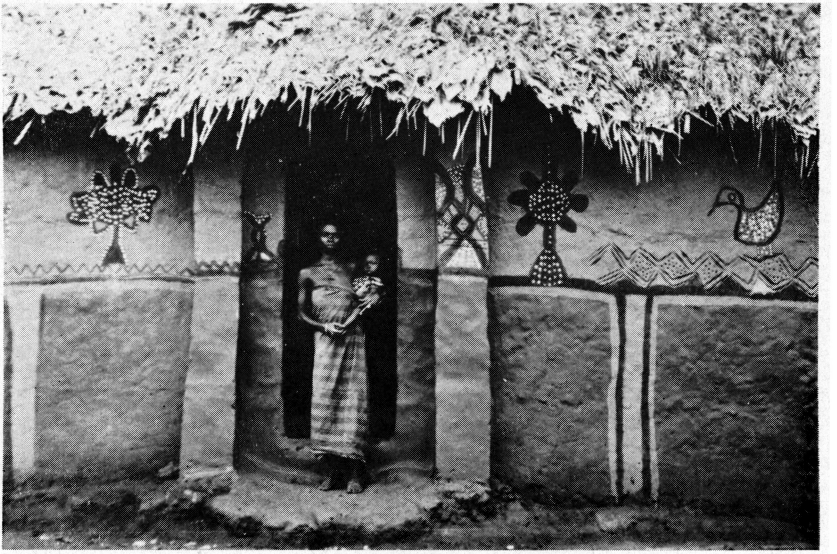
It is comparatively easy to capture the adult mosquitoes in the daytime, when they sit quietly in their resting places. At night, they begin to fly about and seek new people to bite and new resting places, and are then not so easily caught. The larvae of *gambiae* are easy to find, rarely seeking dark, concealed waters, but preferring those well lighted. In the larval stage, males and females are hardly distinguishable; in the adult stage, males are easily identified by their bushy antennae.

If our road became impassable for automobiles, we hired horses. These were practicable for trips of some length, for we could load our baggage on one horse and lead him along with the rest. If the road became impracticable for travel on horses, we sometimes continued on foot.

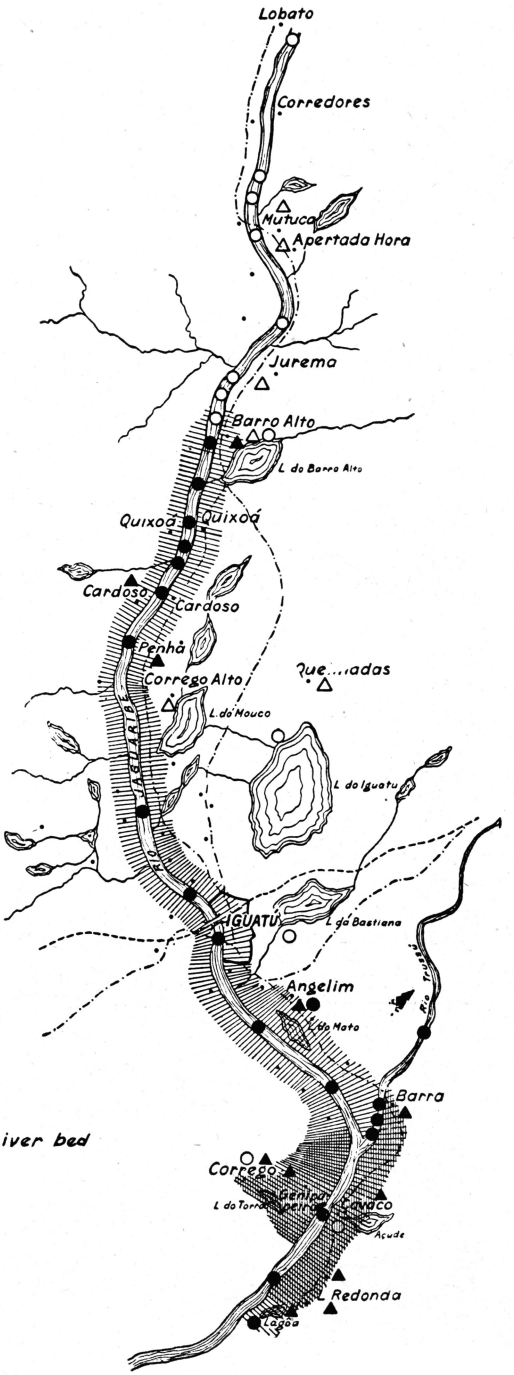
Since it was not always easy to find a hotel or public house of any kind, we sometimes had to live on the country. I have never traveled where certain traveling facilities were more available than in that part of Brazil. In the first place, the people are very kindly and hospitable; moreover, one has to give them little trouble. One could carry his own hammock, mosquito net and all, and we usually carried our own food or the greater part of it. So all our entertainer had to provide was an empty room with strong hooks for suspending the hammock. Hotels were as simply furnished. Occasionally one would find a plain washstand in a room, but always the essential hooks; even the hotel hallways were supplied with them, so that extra guests could be hung up anywhere.

Sometimes, of course, our entertainers would insist on providing food and other conveniences. On one trip our host was a large proprietor—he and his thirteen sons practically managed the

Toll of *Anopheles gambiae*: an Emergency Cemetery in Brazil
By courtesy of The Rockefeller Foundation



An African House



GAMBIAE FRONTIER, CEARÁ, BRAZIL

Scale 1. 71,500
Distance from Lobato to Lagôa Redonda approximately 52 kms.

- ● Larvae of A. gambiae present in river bed
- ○ Larvae of A. gambiae absent
- ▲ Adults of A. gambiae present
- △ Adults of A. gambiae absent
- ≡ Area invaded by A. gambiae
- ▨ Area invaded by malaria in epidemic form

town. There we had food prepared at home and a wealth of sleeping space and hammock hooks. We had the best of food—I remember one tasty beverage compounded of lime juice and the sap of the sugar cane. In that village we found a few *gambiae*, perhaps only scouts, for epidemic malaria had not yet developed there.

In another village, we had time to take blood specimens of a group of twenty-eight children. When I examined these in the laboratory a few days later, I found nine with malaria parasites, in every case quartan. I have often found a high percentage of quartan, as in India, but this was the first time I found one hundred percent. It would be interesting to know if these parasites came from a single refugee who happened to be carrying quartan parasites. We found no *gambiae* in this village, a sandy locality on the seashore, but possibly they had been there earlier in the season; or the malaria may have dated from the pre-*gambiae* epoch.

I have mentioned the severe epidemic at Genipapeiro, where we found only *Plasmodium vivax*. Another village in the same neighborhood had only *Plasmodium falciparum;* so it appears that *gambiae* will carry any kind of malaria to any people in any climate warm enough for the mosquito to breed there.

During one of these surveys we found some interesting breeding places of larvae. I have mentioned that *gambiae*, like *culicifacies* in India, is often lacking in lakes filled with algae and certain other aquatic plants of long-established growth—places where the native anopheles may flourish. But if the lake water is made to seep through soil, it seems to lose its anti-*gambiae* quality and larvae of this species will then grow well in it. I saw one such case where the lake water seeped into the ditches of a small plantation, which was located at the lake margin, where it could utilize the narrow strip of moist soil. The ditches between the plants swarmed with *gambiae* larvae, while in the lake only a few yards away, I could find none of them.

These larvae were the prey of a small species of ant, which stood by ready to pounce on them when the water was nearly

dried away. They were not very effective predators while the larvae had plenty of sea room; like so many natural enemies of mosquitoes they have their own limitations, which may interfere greatly with their usefulness in malaria control. Ants often attack adult mosquitoes, especially those confined in a cage, where they cannot easily escape their persistent enemies. But under natural conditions, mosquitoes often entrench themselves on ancient spider webs where ants cannot follow.

On one occasion, I got a minor thrill in finding *gambiae* flourishing in a distinctly saline water. They were in a large spring issuing from salty soil; and the water was about as salty, I judged, as ordinary soup. It would not have surprised me to find *gambiae* in brackish water in Africa—we often found it in the great lagoon near Lagos, Nigeria—but this was the first time I had found it in such water in Brazil. There seem to be two varieties of the species in Africa, one of them better adapted to brackish water than the other.

The ability to breed in brackish water may be of much importance if this species ever comes to invade the northern continent of this hemisphere. I remember one locality in Spanish Honduras where we found many brackish pools, some of them swarming with anopheline larvae. It was in a region where an underground flow of fresh water to the sea occurred in sufficient volume to sweeten the salt pools, even those at the very margin of the sea. If Honduras is ever invaded by *gambiae*, a not impossible event, such brackish pools may offer a good breeding place for the first colonists.

Intensive anti-*gambiae* measures were taken by the Brazilian government and The Rockefeller Foundation in 1939, and by 1941 the region invaded by *gambiae* was reported free from the pest. As Soper and Wilson state in their report, "*Gambiae* was stopped on its career of invasion, was beaten back, and finally eradicated from the known infested area in less than two years' time."

Even one who has never seen the prevalence of *gambiae* as I saw it can appreciate the magnitude of this achievement. When

I saw the adults swarming in dwellings, and the rivers full of larvae, in the midsummer of 1939, I thought that nothing less than a new labor of Hercules would suffice to cleanse that particular Augean stable. If *gambiae* had chanced to land in the Amazon Valley, where it rains every day, the task might have been impossible. The annual dry seasons prevailing in the *gambiae*-infested part of Brazil favored the work, but this consideration should not detract from the praise due to the leaders in the campaign. Good generals are always alert to avail themselves of the weather or any natural agency they may enlist. In this work, as in war, it was organization which counted most.

Further, this campaign was a timely one. *Gambiae* had a ten years' start and was racing for regions of heavy rainfall where it might have been forever entrenched. There it would have been a menace not only to all of the rainy zones of South America, but to Central America and even to certain parts of our own country; but according to all reports I have obtained, *gambiae* in South America is definitely extirpated and the immediate danger is over. It is true that new arrivals have entered by airplane, but they have not been allowed to colonize.

The two chief weapons employed in the destruction of *gambiae* in Brazil were Paris green and pyrethrum spray, the first to kill the larvae in the water and the second to destroy the adults in human dwellings. The two arms of the campaign were made to supplement one another: if many adults were found in a house, it was presumptive evidence that a breeding place had been overlooked and must be searched for; if, on the other hand, a particularly prolific breeding place were found, then all houses within flight range should receive especially careful attention. The domestic habits of this species, so fatal to man, eventually led to its extirpation. Had the adults been as fond of stables or hollow trees as is *quadrimaculatus* in America, it might have been impossible to kill all of them. But I must mention again that neither one nor both of these anti-mosquito measures would have sufficed without an excellent organization; an army of men led by scientists from two nations enlisted to win a glorious victory.

One naturally asks if the idea of mosquito extirpation could be applied elsewhere. Before discussing this question we should consider certain pertinent factors:

During the past five years a new larvicide has been developed, DDT, which in my opinion—I have tested both—is superior to Paris green. And vastly superior insecticidal sprays and superior methods of using them have been developed. Now we can spray a house and it will long remain sprayed—that is, inhospitable to insects whether bug, mosquito, or fly.

Then funds have to be found. You remember the philosopher who praised Providence because it so often placed large rivers near large cities, where they would be most useful to man. This same Providence, it may be, almost always puts the most malaria among the poorest people, so that generally governmental or other monetary aid has to be sought. But time, both for killing the mosquitoes and paying the bill, is not generally so short as it was in Brazil, and lesser campaigns may be exceedingly useful; the financial problems should not be insuperable.

The matter of boundaries is also important. *Gambiae* in South America was limited, not having had time to spread extensively. Obviously, a limited region bounded by ocean or desert should be more amenable to antimalarial measures than a vast uniform terrain. Again, much would depend on the amount of malaria present and the species of mosquito one would have to combat. It would hardly be practical to try to clean out the anopheles of a county-wide area in the South, especially one containing rice fields. I have ventured the statement that there is not a rural county in the United States, except in high mountains and deserts, where one could not find anopheline mosquitoes, but that a small proportion of counties are malarious.

Of the countries where I have worked, I should think it practical to "de-anophelize" the Siwa Oasis, and probably other desert-bounded localities. If *gambiae* has already invaded Egypt, I should hope that it might be cleared out; perhaps this task has already been done. Possibly the Kyrenia region of Cyprus could be

managed, for it is so nearly surrounded by mountains and sea. We find islands in Almirantè Bay, Panama, where extirpation of anopheles would be very useful, but there a new invasion must be guarded against.

However, much can be done short of extirpation which may render considerable areas safer than they are now, especially those infested by particularly dangerous species of mosquito. I have mentioned Ibadan and Otta Town in West Africa, where thick jungle or other terrain inhospitable to *gambiae* might serve as a boundary, at least a temporary one. I think we might be excused for failure in our attempt to rid the vicinity of Yaba from *gambiae*, for our army consisted of two persons and we were subjected to the inflight of mosquitoes over an area of several square miles. The parcel of ground within mosquito flight of the airports of Equatorial Africa should be made *gambiae*-free, so far as it is physically possible; and similar precautions should be taken in other countries infested by dangerous insects.

It is quite possible that in the hurly-burly of recent war, *gambiae* or other dangerous species may have already escaped to new territory. We cannot be too prompt in making surveys to see if this event has happened anywhere. Not all invasions are as conspicuous as that of *gambiae*, which marked its path in Brazil with a broad trail of sickness and death; but our knowledge of the more dangerous species of the world and of their accustomed habitats is now so complete that no invader should long escape undetected. I emphasize that such surveys should be made as promptly as possible, at least in localities made accessible to dangerous alien anopheles by airplane or other rapid transportation. It would have been comparatively easy to extirpate *gambiae* if it had been vigorously attacked within a few months after its arrival. During the few years it prevailed in Rio Grande do Norte, between 1930 and 1934, it caused several epidemics and did untold damage to life and health. In another locality of Brazil its progress might have been even more rapid and fatal; and one could hardly estimate what it might do today in some rainy coast of India, the East Indies, or Central America.

CHAPTER THIRTEEN: CONCLUSION

The foregoing pages have shown, I trust, how much malaria there is in the world, and how much sickness and death it is responsible for—the amount of malarial illness rivaling that of any other malady, except, perhaps, the common cold. It has reluctantly loosened its grip on some countries, but it has remained strong and active in many others—wet and dry, tropical, subtropical, and even temperate.

Now that we are done—temporarily, at least—with devastating wars, we are free to devote more time and energy to ridding this planet of disease and ignorance; and a more energetic attack on malaria should be one of our earliest tasks. And I believe that a very material diminution of the malady is quite possible. The mosquito enemy is a fragile thing, vulnerable on land and in water and beset with myriads of natural enemies, some of which we can enlist against it. True, its numbers are great, and it may be cunningly hidden; but these considerations should not deter us, who can command such potent measures against insect foes. Even if we cannot always kill, we can win by simply excluding the malaria carrier from our dwellings at night; the anopheles are so stupid that they sit for hours on a screen, never having learned to fold legs and wings in order to penetrate a mesh, an ignorance rivaled only by that of those members of the human species who have never heard of screens.

Such human ignorance is a potent ally of the mosquito. There are few enemies of health more dependent on human shortcomings than malaria, and the ignorance and neglect of a part of a population often endanger the whole. Among the many malarious countries I have visited, I do not remember one which does not tolerate in its midst a considerable lump of people ignorant in vital matters of health and almost always underprivileged in other matters as well. The Negroes and "poor whites" once formed such a group in the southern States of America, and I am not sure that it might not be possible to find some lumps of malaria-

preserving people in this country still; they tolerate the disease among themselves, and the obliging mosquito carries it to their more favored neighbors. My experience with many malaria-scourged peoples has persuaded me that if only one could convince people that mosquitoes carry malaria and teach them a few simple means of protection, a vast proportion of the disease would disappear, almost overnight.

I do not recommend education as a complete substitute for anti-malaria measures conducted by the State or other health institution, but as something which can effectively coöperate in their work, or—as is too often necessary—enable people to undertake some part of the work themselves; for they may have to wait for generations for the State to get around to them, especially in communities impoverished by famine or war. I have described several localities where simple drainage, homemade screens, or an insecticidal spray might accomplish much; and I have mentioned communities where ignorance has led people to build their homes in the most dangerous places to be found, or even to take considerable trouble to canalize the pestilence to their very doors.

Of course, many would say that it is easier to drain the swamp than to teach the people (I would do both if I could), and I do not forget that the measures of the State may promote education of the most effective kind. It must have been an excellent object-lesson for the people of Brazil to see the plague disappear when their government and The Rockefeller Foundation killed the mosquitoes—a rather expensive bit of schooling, it is true, but the "de-anophelizing" of a single stream or swamp should not fail of some instruction if it gives relief to a people suffering with a disease.

I believe that the difficulties of popular education in health matters have been overestimated. It is wonderful to see the growing eagerness for education, even in places where one might not expect to find such eagerness. I once visited a missionary school in Liberia where pupils were punished for some mild infraction of a rule by being kept out of school for a day or two;

and in Nigeria my assistant, Dr. Olinger, saw a strange sight one day—the teacher standing at the schoolhouse door shooing the children away from it. The pupils owed for their tuition, but evidently they wanted education—on credit, if they could get it in no other way.

We need not be discouraged if it requires a generation or two among some peoples to accomplish much education, and a good way to begin it is to utilize the natural curiosity of children. In our field work, we often saw children crowding around to watch what was to them a curious sight—a stranger armed with a pail and dipper, scooping up mosquito wrigglers, perhaps in their very dooryards. If the stranger tells them that he is catching mosquitoes which carry their fever, they may not believe nor may their parents, whom they tell about the odd thing they have seen. But the next generation of children and parents may be more inclined to listen.

I have had some experience in teaching children health through natural history, and I know that it is quite possible to interest pupils and hold their attention, even unaided by "requirements," promotion, or grades. I would begin health education in this country (where it is sorely needed), and in malaria instruction I would make use of simple means—like a fruit-jar, or other aquarium, set in the schoolroom window, where pupils could see the various stages of mosquito development—elementary instruction which would prepare their minds for learning the rudiments of malaria transmission. Such information might be very helpful in rural neighborhoods in those parts of our country where malaria still prevails.

Everywhere in the world, in my experience, we can avail ourselves of the fact that there is no taboo in favor of the mosquito; it is a pest everywhere, and does not have to be spared for any reason whatsoever. It was different with flies in the Egyptian villages where the mothers brought us their "withered," dysentery-scourged babies; the people thought that the flies, swarming on the lips and eyes of the children, were beneficial to them, and mothers might first have to be taught that the babies could get along

without these insects. But nobody loves a mosquito or wants to preserve it.

This swiftly changing world demands of all of us that we keep up our own education especially as concerns the spread by rapid transportation of dangerous disease and its carriers. We have seen what disaster was brought to Brazil by the chance importation of a single mosquito species, and we should remember that its source, West Africa, is very large, is heavily infested, and is now situated on various highways of travel.

Further, we may expect a great increase in the amount of irrigation during the next few decades, since so much of this planet is dry where it needs to be moist. The new powerful atomic explosives may open a peaceful way, even in parts of the Sahara Desert, for water to enter millions of acres now considered hopelessly arid; and we have seen how many countries become malaria-infested through irrigation. If we cannot introduce the good without bringing in the evil with it, we cannot expect the unmixed thanks of our day and generation.

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