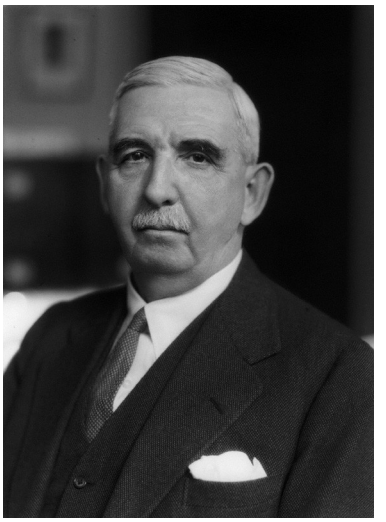
Rural Sanitation in the Tropics

Being Notes and Observations in the Malay Archipelago, Panama, and Other Lands

by Malcolm Watson
M.D., C.M., D.P.H.



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Electronic edition 2015 prepared by Michael Palmer, MD

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Foreword to the electronic edition, 2015

As of 2015, this remarkable book is exactly one hundred years old. It was written by an outstanding pioneer of malaria control. Sir Malcolm Watson, when serving as a sanitarian in Malaya, devised and oversaw the world's first successful large-scale effort to control malaria in what was then a British colony. In the first part of this book, he describes this work. He does so in an understated way that hardly does justice to his own role and contribution; Watson succeeded at a time when other large-scale efforts failed, such as that at the British military base in Mian Mir, India. His contemporaries recognized his accomplishments, however, and when he wrote this book, he was already a celebrity, as is evident e.g. from Section 14.7.

The central part of the book is devoted to the sanitary work done by the Americans in Panama, which Watson visited when the construction of the Canal was in full swing. The conditions of the climate, combined with the continual environmental disruption caused by excavation and construction, were extremely conducive to the spread of yellow fever and malaria, which had caused the previous French construction project to end in failure and disaster.

When the Americans took over, they brought in Colonel Gorgas, who had been part of the team around Walter Reed that had discovered the transmission mode of yellow fever and subsequently driven the disease from Havana, Cuba. In Panama, Gorgas created a uniquely effective sanitary organization that achieved the elimination of yellow fever and the tight control of malaria, thus ensuring the health of the workforce and the success of the construction project. Watson gives a vivid and detailed account of this large-scale sanitary work, and he provides an insightful discussion of the challenges which the Americans faced and ultimately overcame.

Throughout the text, Watson displays a keen eye for detail, but also a broad, understanding outlook on the general conditions of life and work to which sanitary rules and provisions must be adapted. An open mind, a keen scientific interest, and a strong practical sense round out the set of qualities that allowed him to succeed where many others failed.

Watson's account is historically interesting, but its relevance is not limited to history alone. Considering that malaria is often perceived as an almost insurmountable challenge even in our scientifically advanced age, it may be quite startling to read how pioneers like Watson and Gorgas managed to get the better of it, using careful surveys of mosquito breeding places, followed by simple measures such as drainage of swamps and creeks, and oiling of standing water.

It bears mention that, later on, Watson and his co-workers put this approach into practice successfully also in Africa, in some mining towns of what is now Zambia (see his book *African Highway: The Battle for Health in Central Africa*; John Murray, 1953). Overall, Watson showed that simple measures of environmental management, if thoroughly and diligently applied, will effectively control malaria in virtually any geographic setting. This lesson has lost nothing of its relevance today, and for this reason, his book remains important one hundred years on.

About this edition

I obtained the page scans of the original edition from `archive.org`. For this version, I have reformatted the text, and made some minor editorial changes, as follows:

- The titles of chapters 2–3 and 8–16 (which read like "Panama" and "Panama, continued" etc. in the original edition) were extended to better reflect the scope of each chapter.
- Section headings have been arranged into two hierarchical levels instead of one, and occasionally new section headings have been inserted.
- Many long paragraphs have been broken up into shorter ones where this seemed appropriate. Some sentences have been very slightly altered or rearranged, mostly in order to avoid bad line breaks. Their meaning has remained unchanged.
- Hyphenation and spelling have been gently (but incompletely) updated.
- All tables have been numbered and given captions, and they are now referred to in the text using these labels. A list of tables was added as well.
- Figures have been moved closer to the text referencing them, and this has sometimes caused them to be reordered slightly. In some cases, figures that were numbered separately have been combined as panels A and B of a single figure. Figures have also been renumbered relative to the containing chapters.
- Photographs that appeared in landscape format in the original edition have been reduced in size and reoriented to portrait format, since the limited quality of the scanned images did not seem to warrant the use of space and impediment to ease of reading.
- Several plots and charts that were poorly legible in the original page scans were digitized and recreated using Gnuplot.
- Some tables and other material have been moved from the running text to a newly created appendix.

In sum, while the layout has been gently updated, the content is essentially unchanged. However, if you prefer, an unaltered reproduction of the original book is also available from my website.

Michael Palmer, May 2015

Preface

In the text I take the opportunity of expressing my thanks to many of my colleagues in the medical profession, and others who so generously helped me in the different countries that I visited. Here I wish to tender respectfully my thanks to His Excellency Sir Arthur Young, K.C.M.G., Governor of the Straits Settlements and High Commissioner of the Federated Malay States, for the credentials with which he provided me; to His Excellency Sir Walter Egerton, K.C.M.G., who invited me to make my headquarters at Government House, and in other ways assisted me in British Guiana; and to Colonel Goethals, Governor of the Isthmian Canal Zone, and Colonel Gorgas, for their assistance in connection with my visit to the Panama Canal. And finally, for revising the proofs of this work and for seeing it through the press, I am indebted to George S. Middleton, M.D., LL.D., late Senior Physician to the Glasgow Royal Infirmary. To find myself again associated in work with a beloved Teacher and inspiring "Chief" brings back the breath and bloom of the happy years spent in the G.R.I.

M. WATSON

1. Introductory

To one who, like the author, has the direct responsibility for the health, and so for the efficiency, of a large force of tropical labourers, the unavoidable isolation from fellow workers is a source of constant anxiety. Ever before him there is the fear that his views may become narrow and fixed from constantly seeing the same surroundings, and that his ideas would be altered had he more knowledge of what was happening in other places. The waste of only a single cent a coolie a day on a labour force of forty thousand means a direct loss of 126,000 Straits dollars (almost £15,000 sterling) per annum; and to increase the efficiency of the labour by a cent a day means a corresponding gain. Books and papers are valuable; but of more value still is a meeting with their authors, and an actual view of the field in which they work. Such thoughts and such fears have driven the writer to spend time and money in visiting other lands, so that he might benefit those under his care. In this book I have recorded what I saw and what I thought.

It includes a detailed account of the sanitary organization in Panama, the Mecca of the modern sanitarian. There he learns how one of the largest labour forces that the world has seen has been built up, and kept at a high degree of efficiency, in one of the deadliest climates in the tropics, when engaged on a great engineering work. My visit to British Guiana was made to determine the health conditions of another large labour force, also in the American tropics, when engaged in agricultural pursuits. But as a man, however careful he may be, can hardly help seeing through his own spectacles, I have begun with a chapter on sanitary work in the Malay States, and have there recorded some of the conclusions to which I have been led, and which seem to me to throw light on malaria in Italy, India, other parts of Asia, and the great Eastern Archipelago. My visit to Sumatra showed what excellent work is being done there to improve the health of large labour forces engaged in tropical agriculture.

Everywhere throughout the tropics great sanitary activity, and scientific investigation of disease, have followed Ross' epoch-making discovery of the role played by the mosquito in the propagation of malaria. From India, from the Philippines, and from other countries, a series of invaluable reports are being issued, which will before long go far to make the tropics, if not a permanent home for the white races, at least a part of the world in which the white man may live with little more danger to health than in his own country. From the early chapters the reader will be able to gauge the views, and perhaps the bias and prejudices, of the author, when he set forth on his travels.

2. British Malaya: malaria control in Klang district

2.1 History

Surveying the recent history of Egypt, Lord Cromer writes: "It may be doubted whether in any other country such a remarkable transformation has been made in so short a time." Had he, however, turned his eyes eastward to the Malay Peninsula, he would have found a transformation no less remarkable, and due, moreover, to administrators of no other than his own race. But if the happy results from brilliant administration are the same, the parallel ends there. In Egypt the administrator revived a country whose civilization is the oldest in the world, and rescued a people whose history forms the earliest records of the human race; in Malaya a new country appeared newborn from the womb of Time, where it had slept since the world began. In Egypt engineers brought water from a river to a sandy waste, and turned a barren desert into fruitful fields; in Malaya a jungle, watered by the copious rains of heaven, covered the country as an evergreen robe; and if, for a time, man's efforts have driven it back, silently and stealthily it ever seeks to resume its sway. In Egypt an industrious people were the victims of virile alien hordes; in Malaya a scanty thriftless native race preyed on the few who came to work. Egypt was made great through the industry of her own people in her fields; Malaya has become fruitful by the peaceful immigration of strangers who work mainly in her mines. But in both countries firm and honest rule has brought an era of peace and plenty, of which our race may indeed feel proud.

Forty years ago the Malaya Peninsula slept in her jungle, hardly disturbed by a few Chinese miners, who scratched the surface of the soil in search of tin. Her own people, the Malays, lived on the rivers, for there were no roads; grew a few grains of rice, and a few bunches of fruit; possessed no property, for that only made life more insecure; and robbed the Chinese miner or any other passer-by, if he seemed too weak to resist attack. From time to time, perhaps for the sake of variety, they molested the traders of the neighbouring British colony.

At last a peculiarly brutal piracy committed on a British ship, and the impossibility of tolerating almost continuous strife just without, and sometimes within, her borders, drove the governor of the colony to assume a certain control over the native rulers. By degrees, and to the great advantage of the whole land, the administration passed into the hands of the British. Peace being established, the Malay now felt secure, and in a land so fruitful soon accumulated what to him was untold wealth. Sure of the fruits of their labour, the Chinese poured into the country, and worked with such vigour that the Federated Malay States have for a generation past produced almost two-thirds of

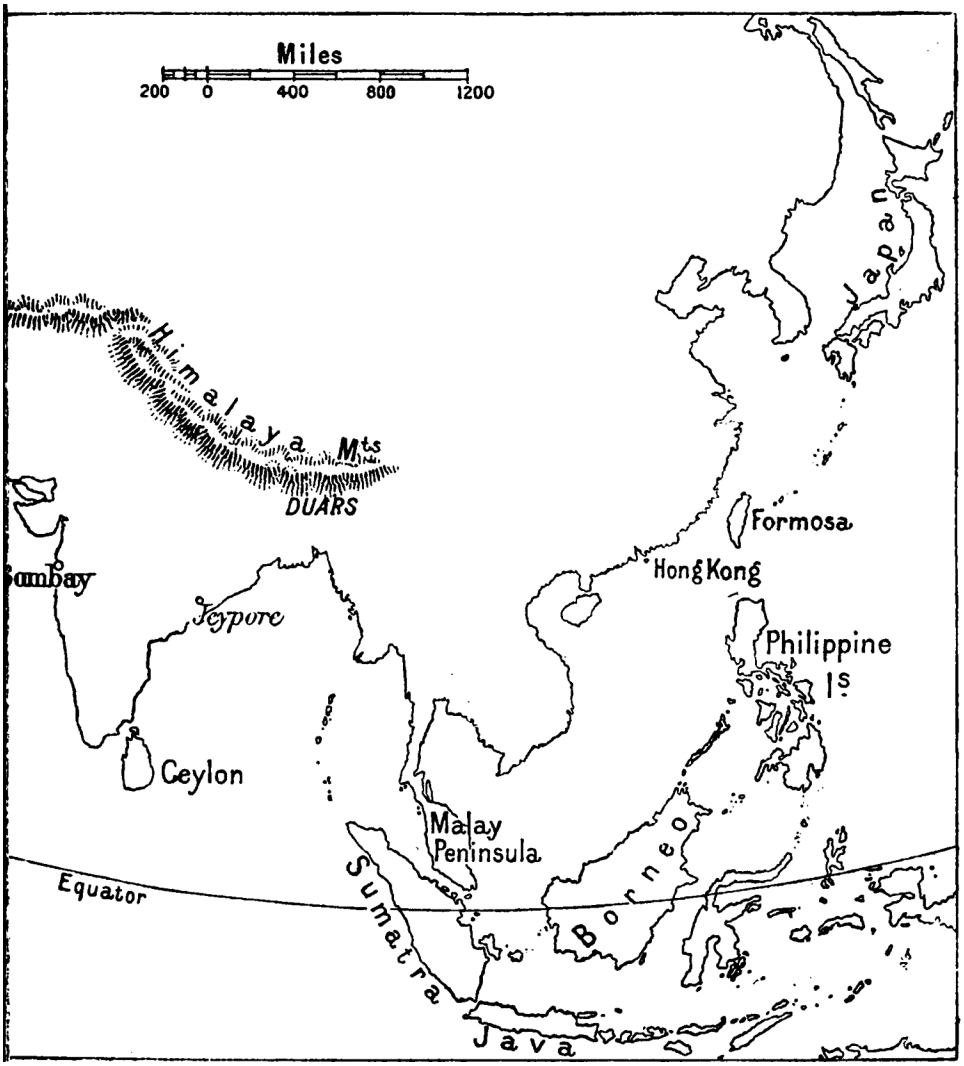


Figure 2.1 Map of South East Asia

the world's tin. Wisely expending the revenue from tin on roads and railways to open up the country, the administrators attracted planters from Ceylon, who grew coffee, rubber, and cocoa nuts, and turned useless jungle into wealth both for themselves and the country; until in the space of one generation the country became one of the most prosperous on the globe. Towns with well-built houses, broad streets, and pure water supplies have sprung into existence where only a few years ago the tiger hunted his prey.

There are schools for the children, hospitals for the sick, and pure justice for the litigant and lawless; while posts, telegraphs, roads and railways, second to none in cheapness, link up the whole land. And all this prosperity has been built up with labour

which has been "free" in the truest and broadest sense of the word. A slave there has never been. At first there was a small percentage of labour indentured to remain on the mine or estate for a period not exceeding three years; but even indenture is now abolished. No coolie can be charged even with the cost of bringing him to the country; while he may walk off at any time on giving a months notice, or paying a month's wages. The proof of the success of the system has been the large number of poverty-stricken coolies who came from India and China; the large sums remitted back; and the prosperity of the whole country.

But from time to time the immigrants found themselves checked by those diseases, often so mysterious in their origin, which have haunted and harried all attempts at tropical colonization. Of my experience of malaria, the greatest, or shall I say the worst, of these diseases, I now propose to write; adding later on some remarks on beri-beri and other sanitary problems.

2.2 Klang and Port Swettenham

2.2.1 Klang. On assuming duty as District Surgeon of Klang, Federated Malay States, early in January 1901, I found that a very large percentage of the patients in my hospital suffered from malaria. Not only was the town of Klang full of malaria, but the whole coast-line was suffering from a "wave" of the disease. The little town of Jugra, twenty miles south of Klang was so unhealthy that a proposal to remove it bodily was being discussed. As a student of the London School of Tropical Medicine, I was familiar with the malaria parasite, and I was also aware of Ross' discovery that *Anopheles* carried malaria. It appeared to me that ward after ward might be built to accommodate the increasing number of patients without any very substantial advantage to the community; for only a small fraction of the sick would ever come to hospital; or, if they came, could be accommodated in the hospital, however much it was likely to be extended. It was clear to me, that, even at the risk of being accused of neglecting my patients and "wasting my time on research," it was my duty to spend some of my time in studying the disease outside of the wards, and to make some attempt to prevent people from getting the disease.

2.2.2 Choice of anti-malaria method. It was necessary first of all to obtain an accurate knowledge of where the malaria cases came from, and statistics were carefully prepared. The breeding places of *Anopheles* were next sought out, and marked out on a plan. Then came the really difficult question, what method was to be adopted to stamp out the disease. Medical opinion was strongly divided then, as it was to be for many years after. Fortunately I made what was to prove in the end, the right choice. The position will be realized from the following paragraphs extracted from an earlier work of my own:[1]

> At this time, Ross' brilliant discovery had been fully confirmed by the Italians and others. Manson's dramatic proof at Ostia and at London left no doubt of what could be done under certain conditions. Ross himself had favoured mosquito reduction, and was actively engaged in West Africa in putting this method to the test. The Italians were rather

[1] *The Prevention of Malaria in the Federated Malay States*, by M. Watson, p. 14.

in favour of mechanical prophylaxis by mosquito netting, and by the use of quinine, and Koch had already reported a success in a small community by the regular use of this drug.

At this time nothing was known about the species of Anophelines, and the valuable reports of the Commissioners of the Malaria Committee of the Royal Society bearing on the importance of species were not published until the year after the works at Klang had been begun.

At Klang the work of eradicating malaria seemed well nigh hopeless. No hot or cold season even temporarily stopped the mosquito pest, and every well, ditch, and swamp teemed with larvae.

The active co-operation of the native community could not be expected, and active resistance, especially from the Chinese, was certain if any attempt were made to enforce the use of quinine. The enforcement of mosquito nets was, of course, impossible, since this would have meant constant house visitation at night. Compulsory screening of the whole of all the houses was impossible, for financial reasons. The large acreage of swamp, the heavy rainfall, and the amount of supervision required, apart altogether from its cost and temporary efficacy, prohibited the use of petroleum.

Again, with an area so extensive, subsoil water so high as to form permanent swamps, and aquatic vegetation so dense, the sweeping out or dealing with the individual collections of water in any continuous manner was impossible. As Surgeon of a district fully 100 miles long, I felt that the time I could devote to any anti-malaria measures would be limited, and I also felt that no other member of the community was at all likely, either to be willing or able, to give more time than myself to the supervision of measures which would only keep down mosquitoes as long as they were constantly applied. And, to be quite candid, knowing that the burden would fall on myself, I did not quite appreciate the idea of having constantly to stand in the sun supervising coolies, and insisting on that thoroughness on which alone success would depend.

Considering all these elements of the problem, I rejected as impossible Koch's quinine method, and the Italian mechanical prophylaxis, and decided to recommend Ross' method of mosquito reduction. To suit the local conditions I determined that any expenditure should be on works of a permanent nature. By draining and filling there would be a large and permanent reduction of the breeding places of mosquitoes, and presumably malaria would be correspondingly reduced.

A proposal was made to Government that Klang town should be drained, to test the new mosquito theory; and the money was at once voted. Work was begun at once by the Sanitary Board, and within a couple of years malaria had ceased to be of any practical consequence.

2.2.3 Port Swettenham. On the 15th September 1901, this new port was opened, and a considerable official population was removed from Klang to it. Almost immediately malaria became so severe that work could not be carried on properly either by the shipping, the Harbour Department, or the railway; and two months later the High Commissioner ordered the closure of the port until it could be made healthier. In the meantime a local commission had been appointed, and it recommended that instead of closing the port an attempt should be made to make it healthier by carrying out certain sanitary measures recommended strongly by me in the previous April. As the site of the town was below high-tide level—in fact, the houses were built in a mangrove

Table 2.1 Hospital admissions and death rates due to malaria in Klang and Port Swettenham

Hospital admissions in Klang, Port Swettenham, and other parts of the district

Residence	1901	1902	1903	1904	1905
Klang	334	129	48	28	12
Klang and Port Swettenham	88	-	-	-	-
Port Swettenham	188	70	21	4	11
Other parts of district	197	204	150	266	353
Total	807	403	219	298	376

Deaths in Klang and Port Swettenham, corrected for deaths occurring in hospital

	1900	1901	1902	1903	1904	1905
Fever	259	368	59	46	48	45
Other diseases	215	214	85	69	74	68
Total	474	582	144	115	122	113

swamp, the trees of which were often within 50 feet of the houses—embankments were constructed to keep out the sea; and tide-valves were affixed to the ends of the drains, so that while water could escape at low tide, no seawater could enter. In addition to drainage, all pools were oiled; and quinine was offered to and taken by many of the people. In a short time the work of the port was proceeding as if such a thing as malaria had never existed.

2.2.4 Results. As a result of the drainage of these two places, the number of cases of malaria admitted to hospital fell very rapidly, which was in marked contrast to the surrounding district. There was also a remarkable diminution in the number of deaths, as shown in Table 2.1.

When the diminution in the number of deaths from other diseases than malaria was first observed, I was puzzled. It was possible to suppose that the improvement in health was not due to malaria having been driven off; but that there had disappeared some unrecognised malign influence which had in some way affected everyone, and made many succumb easily to all diseases, including malaria, and that the removal of this had enabled everyone to resist malaria and all other diseases more successfully, I could think, however, of no general cause which could have so acted; food, climate, water, everything were identical. Then the explanation flashed on me.

In my hospital work, a long series of blood examinations from patients who made no complaint of malaria had shown me that many people harbour the malaria para-

site without having high temperatures; that even when their temperatures are high, they may be quite unconscious of the fact; but that such people suffer from abscess, diarrhoea, dysentery, etc., because their weakened health makes them easy victims to the attacks of such disease germs. This being so, then the elimination of malaria from a community would not only prevent deaths that were recognisably due to malaria, but it would also prevent the deaths of many who succumbed to diseases that were really unrecognised sequelae of malaria (a microscopic examination of the blood would have shown the true connection); and that unrecognised malaria itself was in fact the "unrecognised malign influence" which had disappeared.

2.3 Rural malaria

2.3.1 Malaria easily controlled on flat land. The drainage and filling of swamps in the towns of Klang and Port Swettenham had cost respectively about $30,000 and $50,000,[1] and the areas dealt with had amounted to only about 300 and 100 acres, respectively. Certainly, at that cost per acre it would be impossible to free the surrounding districts from malaria. But a study of the adjoining district of Kuala Selangor led me to think that "the stamping out of malaria, or at least reducing it to a negligible quantity, is a much more hopeful affair than has been hitherto anticipated."

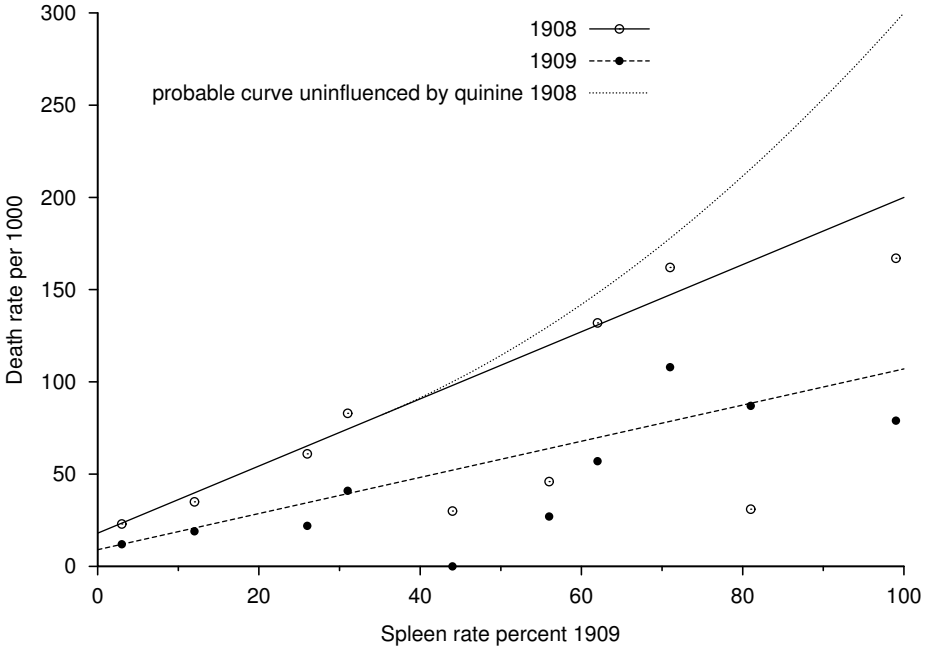
From the study of that district, I felt justified in urging the better drainage of the Kapar portion of the Klang district; and after inquiry the Government voted the sum of $110,000 for the Kapar Drainage Scheme. Thirty-seven miles of main drains about 20 ft. wide were cut or improved, and this enabled planters to drain 24,000 acres.

To me this great agricultural development was a great experiment in the prevention of malaria. It was a unique opportunity, and I determined to spare nothing in an attempt to understand it. Accordingly I began a systematic examination of the blood of children on different estates; and also charted the different species of *Anopheles* found in different parts of my districts. After I had carried out this work as a hobby for a considerable time, giving planters all the assistance I could in order to improve the health of their labour forces, I was asked to become medical adviser to a large number of them. This enabled me to improve my transport, and being in the confidence of the planters, to count on their cooperation and help in the work I was attempting.

To cut a long[2] story short, I have traced from year to year the steady disappearance of malaria from 500 square miles of country.

A definite connection was traced between malaria and its carrier, *A. umbrosus*, which bred in stagnant pools in the jungle; and it was proved that the abolition of these pools occurred when land was drained and cultivated. I made observations on the parasite and spleen rates, so we have considerable data. It was also shown that the spleen rate diminished the further we passed from the jungle pool; that the death rate was intimately connected with the spleen rate; and that about half a mile from the breeding place, malaria had disappeared. We had thus made the important discovery that in low-lying alluvial clay soil with a high ground water—the great stronghold of malaria—we had complete control over the disease. So complete was our control that

[1] A dollar = 2 shillings and 4 pence sterling. [2] Full details will be published shortly in a new edition of *The Prevention of Malaria in the Federated Malay States*.



Year	Number of coolies on which results have been obtained									
1908	7,106	492	2291	1121	65	767	1,738	1,165	180	973
1909	8,210	658	2,120	1,526	27	842	1,602	904	150	943

Figure 2.2 Chart showing variation of death rate with spleen rate in Klang District

the simplest possible rules could be laid down for practical men. They were, either (1) remove your habitations to a distance of half a mile from the jungle pools, or (2) fell jungle and drain jungle pools for a similar distance. These two simple measures have been extensively used, with the result that the true spleen rate of many estates is zero (any children with enlarged spleens being new arrivals from malarious places); and the death rates are from 5 to 20 per 1000, including all women, children, and dependants; while the total admission rates from all diseases are down to 100 per 1000, and malarial admission rates are under 20 (these, again, mainly due to new arrivals who have come from malarious parts of the peninsula).

By attention to these rules new estates of thousands of acres have been opened without ever suffering from malaria. But we have one unfortunate estate which reversed the process ; it put coolies near to the jungle, with the result that the force wasted away from 600 coolies to about 300. The spleen rate rose from 3.7 to 58. The daily sick in hospital rose from 2 to 30; the outpatients, from 8 to 90; and owing to this sickness the labour was insufficient to tap the trees, and the manager failed to get his estimate by 30,000 lbs. of rubber, a loss of some £7000. I could not account for the outbreak. As far

as I knew, and I thought I knew the estate, no coolie lines were within half a mile of the jungle, and the manager assured me this was so. But at length, having failed completely to find a breeding place near the lines, I set out to examine the boundaries of the estate, and found they bent in near to some new lines. A redistribution of labour had mixed up all the coolies, and so I had been unable to trace the outbreak to its origin at first. The moral is that a medical officer should not merely think he knows an estate, but by actually visiting every part of it, know it from personal examination.

Finally, there is an interesting instance when a spleen rate dropped from 50 to 5. The jungle, from which the malaria came, apparently remained unaltered. I was, however, convinced something had happened to the jungle, and stated my conviction to the manager. He then reminded me that it had been drained, though not felled, by the neighbouring estate in connection with their water supply. This obviously was the explanation, and furnished another instance of the connection of malaria with jungle pools on low, at coastal lands, and its disappearance on the drainage of these pools.

2.3.2 Hill land; persistence of malaria. The malaria problem now seemed to be solved in the Federated Malay States: we might expect the disease to disappear of itself with the extension of cultivation. But in 1909 I had to abandon this idea in so far as it related to many of the hilly districts in the Federated Malay States. It was perfectly true that one or two estates where the land was hilly were perfectly healthy; these indeed obscured the problem. But ninety nine out of a hundred hill estates remained as intensely malarious as they had been when first opened. We had succeeded in eradicating malaria from the place where we least expected success—in the low-lying coast land with a stiff clay soil and high ground water; we had failed completely where we least expected failure—in our beautiful hill land, where swamps were conspicuous only by their absence, and the only water was the crystal spring and brook. In hill land the admission rates to hospital often ran to 3000 per mille per annum of the population, and the death rates, which averaged 150, often leapt to 400 and 500 when many new arrivals came to an estate. The European staff suffered as much as the coolies, and the highest Government officials were not exempt. Public works no less than private enterprise were time and again almost brought to a standstill. Quinine, tried in every shape and form, completely failed to eradicate the disease, although it lowered both the admission rate and the death rate.

The reason for the persistence of malaria in hill land proved ultimately to be ascribable to the different habits of the carrier by which in these regions it is conveyed. The carrier is *A. maculatus* (in those days we knew it as *Anopheles* or *Nyssorhynchus willmori*), which breeds in clear springs and crystal brooks, and cannot be eradicated by weeding the edges of the stream. In spite of quite a strong current it can hang on to rocks and pebbles in a stream where not a blade of grass or other aquatic vegetation is to be found; although it is no less at home when a stream is full of grass, provided there is a sufficient flow to keep the water fresh. I came to the conclusion, therefore, that *unless we could alter the composition of th water in these hill streams in such a was to make it uncongenial to all malaria-carrying mosquitoes*, the only way we could get

rid of the insect (and malaria) here would be by putting the streams underground in pipes.

Having seen estate after estate become healthy on the low coast land, as we got rid of *A. umbrosus*, I was convinced that the right way to deal with the hill-land malaria was to strike directly at the mosquito larva, rather than to put people inside screened houses. I proposed that the population of an estate should be concentrated on one or more sanitary areas, and that all water for a certain distance round the areas should be carried off underground in ordinary agricultural pipe drains, such as we are familiar with in Europe.

I suggested such a scheme for Seafield Estate, where I was satisfied the work would be done with the thoroughness necessary for success. Few men, whether they be medical men or laymen, had striven harder to overcome the pestilence than Mr H. R. Quartley, Manager of Seafield Estate. It was because of the thoroughness with which quinine had been given to the coolies on Seafield Estate over a period of several years, that I was convinced quinine alone could never do all that Koch and the Italians claimed for it. And it was because the streams on Seafield had been scrupulously clean-weeded over a period of four years with the definite object of eliminating *A. maculatus*, that I felt entitled to say that no treatment on such lines of these streams would eliminate the mosquito. This mosquito had been proved up to the hilt to be the chief offender. Its larva we could find in the streams; the adult insect could be caught in the coolie lines, and on dissection 20 to 25 percent were found to have malaria parasites in their stomachs or salivary glands. Unless we could abolish malaria, we could never establish a healthy labour force sufficient to cultivate the estate; and on Mr Quartley laying all these facts before his directors, they agreed to spend £3000 sterling on an attempt to make the estate healthy.

2.3.3 Subsoil drainage and its problems. When we had reached the conclusion that subsoil drainage was necessary if malaria was to be overcome, the practical application of this measure presented many problems. Panama, where it had been employed for a hundred yards round buildings, in conjunction with oiling and screening, gave no help; and, as I have since learned, it is not essential to the successful result there.

2.3.4 The area to be drained. It was important to know the area requiring to be done. This obviously was related not so much to the distance an odd mosquito might fly or be blown from its breeding place, as to the distance at which there would not be a sufficient number of mosquitoes to furnish the complete and complicated chain of the parasites life from man through the mosquito to man. This on the flat land was shown to be about 40 chains (half a mile) from the jungle breeding pool. These measurements were made from jungle which generally existed as a menace to health only on one side of the coolie lines, for, as a rule, there was a wide stretch of opened land on other sides. In other words, the mosquitoes on at land came from only one direction.

Our proposal for hill lands was to create a mosquito-free circle, into which, presumably, mosquitoes would pour from all points of the compass. Would 40 chains be enough under these circumstances? It seemed to me to be well worth trying less than 40

chains, for two reasons. The first was that, on the hill land, mosquitoes would not really fly in from all directions, for part of the boundary of the circle would be high dry land not breeding mosquitoes. Mosquitoes would in reality be breeding only in the ravines, and the mosquito attack on the coolie lines might be likened to a series of columns (the number depending on the number of ravines) advancing on a centre.

The second reason was that 90 percent of the *Anopheles* caught on the lines of Seafield were *A. maculatus* (or *willmori*), and only 10 percent *A. umbrosus*. *A. maculatus* is a small and rather delicate mosquito, and it is reasonable to regard its malaria-carrying flight as less than that of *A. umbrosus*, the carrier on whom the flat land measurements were based. It was plain, too, that, purely as a business proposal, it was advisable to work from within outwards, for the area of the work and the expense of the work increases as the square of the radius. To double the radius of the circle was at least to quadruple the expense. Taking all these things into consideration, I was content to begin with about a 30 chain radius. By not draining the quarry ravine on Seafield Estate, we actually were free on one side only for 27 chains.

2.3.5 Stone covering. The pipes in Panama were covered with stone, and then a grass covering was allowed to grow over them; both of value in preventing storm-water scouring out the pipes. Neither of these methods was at first available for Seafield. To have put down stones on the pipes would have multiplied enormously the expense of the work, for little stone is to be found on the estate. It appeared to me that we could do without stone; as has proved to be the case, except in a few places.

I also regarded the use of grass as prohibited; for if, from any unforeseen reason, the piping were to prove a failure, the grass once established in the ravines, would add greatly to the cost of weeding. I was anxious to avoid this; and only approved of grass being grown when satisfied the subsoil drainage would ultimately be effective. How valuable grass is can be seen from the comparative ease with which the anti-malarial work in Kuala Lumpur has been carried out. Before beginning the Kuala Lumpur work the engineer to the Malaria Advisory Board visited Seafield and carefully studied what had been done there; particularly he benefited by the various ingenious methods devised on Seafield to prevent damage from storms without using grass. At Kuala Lumpur the Board's problem was simplified by its being able to use turf and grass to any extent it wished. The excellent results later obtained in Kuala Lumpur owed much to the pioneer work on Seafield, where greater natural difficulties had to be overcome, even apart from the fact that the work was a first attempt.

After a careful survey at Seafield, the late Mr Irvine, Assoc.M.Inst.C.E., drew up a drainage scheme in 1910. The actual work was begun in June 1911, under the supervision of Mr John Bach, Assoc.M.Inst.C.E., and at the end of April 1912 drainage had been carried out to a distance that varied from 25 to 28 chains from the coolie lines. There was a definite, but insufficient, improvement in the health; and in September 1913 the area was extended to give 40 chains in all directions, except one where a deep swamp presented special difficulty to any kind of drainage. It was also found that in the very wet weather of December 1913, the pipes in three of the ravines could not carry away the water with sufficient rapidity to keep the ravines dry; but by June 1914, larger pipes

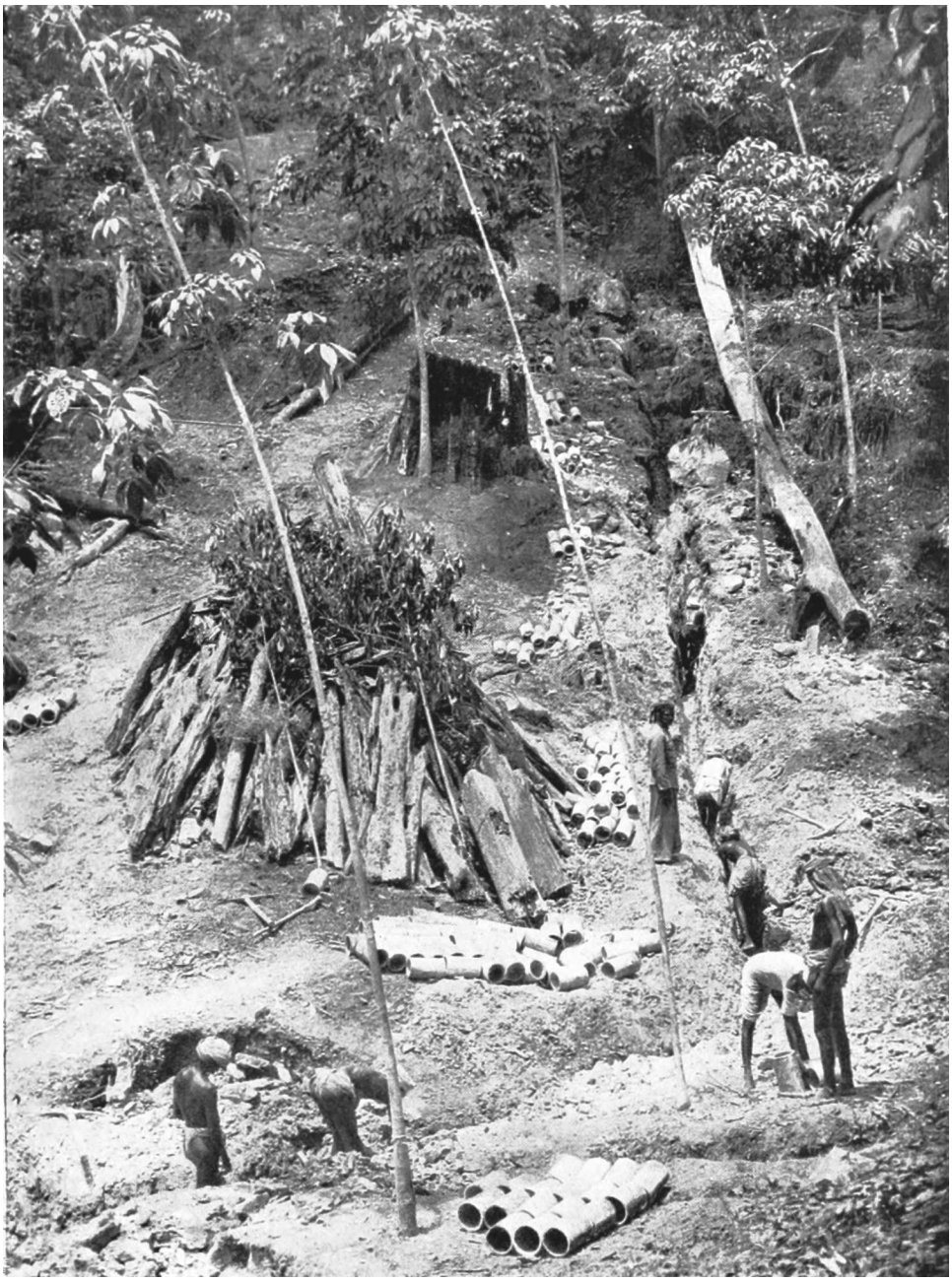


Figure 2.3 Bukit Ijok estate, Federated Malay States. Subsoil drainage to tap springs on the side of a steep ravine.

had been laid down. It is now expected the ravines will remain completely dry and free from *Anopheles* in any weather; and I am confident the long wished-for result will be obtained.

On some hill estates we got rid of malaria very easily; the coolie lines were simply rebuilt on at land at a distance of about 40 chains, or half a mile, from the hills. On one estate a block of 70 acres of low-lying swamp was opened at my suggestion; coolie lines were removed to it from a site on the hills, and the new site proved to be the healthiest on the estate. It was so low-lying and swampy that it had been rejected by the planter; but to the sanitarian it proved to be the chief cornerstone, and after two years trial is now being made the headquarters of the estate labour force.

On two estates where the lines were situated with hills behind and a long stretch of at land in front, it was an easy matter to pipe-drain the hills where alone *A. maculatus* was breeding, and the results were most gratifying. On North Hummock Estate, where this was done, the daily sick rate dropped from 13.5 percent in November 1911 to 2.2 percent in December 1912, and the spleen rate from 11 out of 12 (91 percent) to 2 out of 14 (14 percent), with a corresponding improvement in the general appearance and health of the whole labour force. It will be realized that here we have had to deal with an invasion of *Anopheles* only from one half of the circle, and not from all round as on Seafield. On Bukit Ijoh Estate a similar result followed some difficult drainage carried out most efficiently by Mr N. Fish, the engineer of the estate.

2.3.6 Spleen rates and death rates. I have already spoken about the relationship that exists between spleen rates and death rates, and given a chart to illustrate it (see Figure 2.2). Although prepared from observations made in 1909, later experience has only confirmed its lessons. Of the fatal effect of malaria on a population, it is evidence which cannot be misread; and it also helps us to see in what direction we must push sanitary work, if we are to get the maximum amount of good for the money at our disposal.

3. British Malaya: malaria control in the Federated Malay States

3.1 Malaria Advisory Board, Federated Malay States

In September 1911 the Federated Malay States Federal Government decided to create an Advisory Board for the purpose of dealing with malaria in the Federated Malay States, and invited a few unofficials to become members. It was stated that "The Government has decided to appoint this Board because malaria has become more prevalent, and because it is felt the effectual and efficient control of the disease could be exercised better by a representative Board than by one Government Department." The first members of the Board were, Sir E. L. Brockman, Chief Secretary, Federated Malay States (President); Dr C. L. Sansom, Principal Medical Officer, Federated Malay States; Dr A. T. Stanton, Bacteriologist, Institute for Medical Research ; Mr J. H. M. Robson, Member of the Federal Council; Mr F. D. Evans, Assistant Engineer, P.W.D.; Mr H. R. Quartley, Manager of Seafield Estate; and the writer.

Referring to the objects the Board had in view, Dr Samson writes in his Annual Report for 1911:

> This Board intends
>
> (1) To collect and distribute information regarding malaria;
>
> (2) Advise how anti-malarial measures could be most advantageously carried out in each district;
>
> (3) Encourage and advise local bodies in their efforts towards extermination of mosquitoes;
>
> (4) Draw up appropriate legislative measures.
>
> The dissemination of correct information is of no small importance; there exists in the minds of a great many people, a doubt whether the mosquito carries malaria or any other disease; until this heresy has been corrected it is obvious that in some places preventive measures will only be received in a half-hearted manner and carried out unintelligently. Then there is another group who are inclined to believe that as long as the special malaria carrier is exterminated, other species of mosquito can be allowed to breed with impunity, oblivious of the fact that all mosquitoes are an irritating nuisance, and their constant attacks do not improve health; and more than that, some of them inflict dengue, elephantiasis, and other objectionable ailments. One of the first steps taken by the Board was to begin to arrange for the instruction of all children in schools on the causation and prevention of disease, and that also warning and advice shall be brought to the constant notice of practically all adults. It is felt that systematic diffusion

of knowledge regarding this enemy of man, its habits, the harm it does, and how to exterminate it, will not only encourage the individual to do his share, but also facilitate the efforts of local bodies and probably make them more effectual.

One most important detail connected with anti-malarial work is continuity of policy, of supervision, and subsequent upkeep. It is extremely unsatisfactory if a succession of men are made responsible for the carrying out of one particular piece of work, and changes are to a certain extent inevitable; but with a Central Board, having a settled policy, advising procedure and watching results, not only will preventive measures be more complete, but mistakes obviated. Anti-malarial drainage is not worth undertaking unless it is done very thoroughly—a small spring in a ravine overlooked, will mar the effect of an otherwise complete system.

The remaining objectives of the Board do not require enlarging upon, except that it was decided to carry out a scheme of anti-malarial drainage in a selected area which could be tested, and, if found successful, be used as a model scheme for other similar places. Early in 1911 the Liverpool School of Tropical Medicine published a book entitled *The Prevention of Malaria in the Federated Malay States*, by Dr Malcolm Watson, which contains a valuable record of successful work accomplished by the author, as well as a description of a method of dealing with ravine streams in hilly country, which is nearly always intensely malarious after being opened up.

On two rubber estates in the Batu Tiga district—Glen Marie and Seafield—a thorough system of underground draining has been carried out. The underlying principle was, that springs and streams being favourite breeding places of a very dangerous mosquito, these springs and streams must be conveyed underground, and then the insect will be exterminated. On a larger estate such drainage of all streams would be too costly, so Dr Watson decided to render a certain area completely dry, and place all the inhabitants in the centre of this area.

The next step was to decide upon the method of drainage. Even in a selected area the Panama system was shown to be almost prohibitive, as material would have to be carted very long distances at great expense. So an ingenious idea has been adopted of laying ordinary rough, agricultural pipes along the course of streams, and tapping springs, these pipes carrying all the daily flow; then in order to accommodate the occasional tremendous rush of stormwater, open ditches are made of considerable width, so that scouring is prevented and a storm flow only allowed to develop a depth of a few inches. The method is simple and extremely economical, and if efficiently carried out should prove successful. That pipes get choked occasionally, and from time to time some of them get washed out in exceptionally heavy storms, goes without saying, but replacement is only a matter of a few hours' work and insignificant expense, so that accidents of this sort need not cause anxiety, and it has to be borne in mind that the most expensive drainage pipes and culverts laid with elaborate precautions do not escape destruction by storms.

These experiments are being watched with great interest; they are being carried out by a man of experience, who has studied the subject for some years, and there is every prospect of success. When the system has been thoroughly tested and found good, then every district and estate in hilly country will be able to deal with their ravine streams economically, and both will reap very great benefit. Dr Watson has been kind enough to inform me that the results are encouraging; the figures will be published later on when sufficient time has elapsed.

It appeared to me that the most urgent work before the Board was that of clearing malaria out of Kuala Lumpur, the federal capital. Something like $47,000 had been spent between 1908 and 1911 with this object in view, but without any improvement to the health of the community; for the proper method of dealing with ravine *Anopheles* had not then been studied, and was not available for those actually in charge of the work. I suggested that the Board should undertake anti-malaria drainage in Kuala Lumpur on the method employed on Seafield and Glen Marie estates. The Board approved of this proposal, and Mr Evans, as their engineer, has carried out the work with great care and intelligence. From time to time I have inspected the areas drained, and have found that within twelve hours after heavy rain no water can be found in the ravines.

It is difficult to obtain statistics of the benefit of this drainage; most of it has been carried out in the official residential area. It may be said, however, that malaria is now almost unknown in houses where formerly it was hardly ever absent, and as the Annual Report puts it,[1]

> Amongst the Government officers and their servants who live in the drained area to the west of the railway, practically no cases of malaria have occurred. This is very satisfactory, as the officers and their servants living in this area were repeatedly attacked previous to 1912, when some of the bungalows lay empty at times, because officers preferred not to live in them, despite a shortage of bungalow accommodation.

Definite figures have, however, been obtained regarding the health of the police force, and in the Annual Report it is said that:

> The average monthly percentages of cases of malaria treated in hospital or given sick leave were 35.75 percent, in 1910, 57.01 percent in 1911, 27.33 percent in 1912, and 11.3 percent in 1913. … These figures mean that in 1911, to take the worst case, every Indian at the depot was in hospital or given sick leave for malaria on an average seven times in the year. … It may be mentioned that the improvement was obtained notwithstanding the large increase in density of the population at the depot subsequent to 1911, when in consequence a large number of the men were without the protection of a mosquito net at night. Quinine has only been given to the men under hospital treatment, or to those who come to ask for it.

3.1.1 Quinine. The Board adopted the admirable system of quinine treatment devised in India. It consists of a tube containing twenty tabloids of quinine bishydrochloride, with a printed wrapper giving directions for its use in English, Malay, and Tamil characters. It has been issued free.

3.1.2 Pictorial Card. To educate the public, a coloured pictorial card was issued with the letter-press in English, Malay, Chinese, and Tamil. It was made attractive in design and colour, to induce the native to preserve it as a picture in his house. That it has given the native a full knowledge of the life history of the malaria parasite was neither intended nor expected; and in fact he has had great difficulty in understanding that the larvae and insects are magnified; but what the card did do was to bring home to many thousands of people that the Government believed, and said, that if there were

[1] *Report of the Malarial Advisory Board*, 1913

no mosquitoes there would be no malaria; and that quinine was the best remedy for the disease.

3.1.3 Research. In May 1912 Dr C. Strickland began work as travelling medical entomologist under the Board. He has visited a large number of places for the purpose of studying the life history and habits of the Malayan *Anopheles*, mainly in the hope that some cheap substitute for subsoil drainage would be found. In addition he has published a most useful *Short Key to the Identification of the Anopheline Mosquitoes of Malaya, for the use of Medical Officers and Others*. Before this was issued it was very difficult, if not actually impossible, for a medical officer beginning the study of mosquitoes for the first time to identify a specimen, so inaccessible and confusing had the literature become. For men in the Federated Malay States Dr Strickland's Key removed the difficulty at once.

Although at first simply advisory in function, the Board has found it necessary to undertake a considerable amount of anti-malarial work, and several engineers are now exclusively employed by the Board. It is hoped that in time all the engineers of the Public Works Department will learn the way to lay down subsoil drains; but in the meantime it has been found more satisfactory to entrust the work to the Board engineers. Many large drainage schemes are in progress in different parts of the Federated Malay States.

3.1.4 Terentang Estate Experiment. One of the early problems in connection with subsoil drainage was the policy to be adopted where a stream, too large to pipe, ran through a proposed sanitary area. It was a financial impossibility for most estates to construct any underground channel capable of containing a stream say 20 ft. wide and a foot deep; yet in such streams the larvae of *A. maculatus* have been found. It was always possible that these larvae came from the numerous small lateral feeders of the main stream, and that if these were piped, it would be unnecessary to pipe the main stream; and certain observations made me think this would actually be the case. If it proved to be so, there would be less difficulty in making many estates healthy, for then the main stream could be neglected; if, on the other hand, the main stream still remained a danger, it would be necessary to abandon the idea of creating a healthy site near to such a stream. As the site on a river and a stream is one usually chosen in preference to any other, and as numerous settlements exist on rivers, it was important to learn as early as possible what was the best course to be adopted.

In 1912 I was asked to make a special report on the different properties in the State of Negri Sembilan, belonging to the Anglo-Malay Rubber Company, Limited, and on one of them—Terentang Estate—I found this problem. The Company had spared no expense in promoting the welfare of their labour force, and the excellence of their coolie lines had received special commendation from the Indian Immigration Department. Yet in spite of everything being done which could be suggested, the coolies on this property were decimated with malaria, the death rate in the year 1911 having reached the terrible figure of 384 per 1000. I advised the Company of the special difficulty on this estate, and suggested that, as subsoil drainage in these conditions was essentially experimental, the cost should be borne in the first place by Government, and that

only if the results were satisfactory should the estate be called upon to pay; for if the experiment failed, the community as a whole, though scarcely the estate, would benefit by the knowledge gained. I made the same suggestion to the Malaria Advisory Board, and the Government and the Company having arranged the conditions on which the experiment should be carried out, the work is now in progress under one of the Board's engineers.

Whether the work succeeds or fails in eradicating malaria from Terentang Estate, the experiment will give information of great value to the whole country, as a new aspect of the general problem is here attacked; in the meantime we must wait and see.

3.2 The Anti-malaria Committee of the Straits Settlements

In many parts of the colony of the Straits Settlements, which with the Malay States forms what is often conveniently called British Malaya, and with them forms a geographical unit, malaria has been as severe as in the Malay States; and in June 1911 an Anti-malaria Committee was created in the colony, with the same objects as the Malaria Advisory Board of the Federated Malay States. Curiously enough, just as the most urgent problem in the Malay States was the severe malaria in Kuala Lumpur, the federal capital, so in the colony, it was the health, or rather ill-health, of the city of Singapore, the capital of the colony, which called most urgently for attention. For many years it had been the subject of careful consideration; indeed, some years ago, Professor W. G. Simpson was commissioned to make a special inquiry into the high death rate. In addition to his other recommendations, he advised that drainage of certain portions of the town should be carried out, as had been done in Klang and Port Swettenham. The town had a good water supply, an efficient scavenging system, and a well-equipped sanitary department, and is, in my opinion, one of the best-managed and cleanest large towns in the East.

In spite of everything which could be done, the death rate from malaria was very high; and its effect on the general death rate was so serious, that in the months of May and June 1911 the male mortality rates reached 86.2 and 92.3 per 1000, and the mortality rate for the whole population, exclusive of cholera and smallpox, for June was 81.5. The problem was complicated by the fact that considerable numbers of Chinese were known to come from outside to Singapore when ill, and often died there. In an able report Dr Middleton dealt with the subject of malaria in Singapore, the methods which had been adopted elsewhere, and urged that "a comprehensive and well-considered plan of campaign should therefore be prepared and steadily persevered with, adequate annual appropriations being made for this purpose, both by Government and the Municipality." On his suggestion, I was invited by the Anti-malaria Committee to visit Singapore and advise what should be done in an area which had been selected because it was "known to be malarious, and is not large enough to make supervision difficult."

I did so, and in cooperation with Dr Middleton, Dr Finlayson, and Mr Ball, the acting municipal engineer, drew up a scheme which dealt with every Anopheline breeding place in an area 2 miles long and half a mile wide in the Telok Blanga district, where the harbour is. A house-to-house visit was made, and the number of children with enlarged

spleens was recorded. Dr Middleton, Dr Finlayson, and Mr Ball also visited me at Klang, and I had the opportunity of showing them what had been done there. I made a special point of showing our mistakes, so that they might be avoided in Singapore.

It is too soon to say much of what results have been attained in Singapore. I may say, however, that the work has been admirably done in both Telok Blanga and other districts; and having a thorough grasp of the essentials, the conductors of the experiment have avoided the usual pitfalls.

It would be premature to assert that Singapore has been made healthy; but Dr Middleton was able to record that the death rate, 34.12 for 1913, was "the lowest for nineteen years," and that it "is 7.98 per 1000 below the average annual death rate for the last twenty years." Of even more significance is the alteration in the spleen rate. In 1911 it was 50. Dr Middleton now writes in his report: "Dr Finlayson has found that the spleen rate amongst children at the schools in the Telok Blanga district progressively decreased till ultimately it reached zero, and it is to be hoped that this is an indication that the measures taken will not prove without effect."

If the lower death rate is really due to the reduction in the amount of malaria, it means a saving of fully 2000 lives per annum, as well as the prevention of an enormous amount of sickness; for Singapore is a city with a population of nearly 275,000 people.

3.3 Rice Fields and Malaria

That the formation of rice swamps led to the production of malaria is an old observation, and the attitude of the medical profession has been, very naturally, to view them with great suspicion, and to advise their prohibition within a mile of a town. From my observations on the peculiar habits of our *Anopheles*, the idea occurred to me in 1909 that by converting ravines into rice swamps with putrid vegetation, it would be possible to drive out the dangerous *Anopheles* which live in pure water, and, with them, malaria, without having to spend large sums on subsoil drainage. To determine if this was possible, I examined a large irrigation at Krian, in the State of Perak, and found it to be practically free from malaria. Of 718 children examined by Dr Delemege and myself, only 20 or 2.7 percent, had enlarged spleens. There were, moreover, no less than four species of *Anopheles* present, but the absence of malaria only served as proof of what we already knew, that these species take no serious part in the transmission of malaria. The Krian irrigation area is 66,000 acres in extent. It draws the water supply from a large reservoir made by damming up two considerable rivers. In the reservoir the jungle trees have gradually died out, and the water has a somewhat brownish peaty colour, much like that in the savannahs behind the sugar estates in British Guiana.

A little farther south there are a series of rice fields in Bukit Gantang valley: they are irrigated by water coming directly from the hills; not having been stored in a reservoir, it is purer than that of the Krian rice fields. In this valley I found severe malaria among the children, the spleen rate varying in different schools from 43 to 61; and in addition to the four species of *Anopheles* found at Krian there were three others, one or all of which presumably must carry malaria. As a matter of fact, I had already found one to be a carrier in nature, and subsequently Dr Stanton showed that another (*A. albirostris*) is

Table 3.1 Species distribution of *Anopheles* taken at Bukit Gantang valley and Krian. Proven malaria vectors in boldface.

Region	At the foot of the hills forming Bukit Gantang valley	In the rice fields of Bukit Gantang valley	In Krian irrigation area
Malaria abundance	high	high	nil
A. maculatus	+	−	−
A. albirostris	+	+	−
A. umbrosus	+	+	−
A. fuliginosus	+	+	−
A. barbirostris	+	+	+
A. sinensis	+	+	+
A. kochii	+	+	+
A. rossii	+	+	+

also culpable. In the hill streams at the sides of the valley, *A. maculatus* was discovered in abundance, but in the rice fields it was never found. Table 3.1 shows clearly the results of the investigation.

Although I was unable to utilise the information I had now gained for the purpose of clearing malaria from the ravines of hill estates, the investigation showed that rice fields may be free from malaria; and from these and allied observations I suggested that, in the future, it might be possible to eradicate malaria from certain places by altering the composition of the water in such a way as to make it uninhabitable for some particular malaria-carrying mosquito. It was, therefore, with the greatest interest that I found in 1913 that one of the most dangerous malaria-carrying *Anopheles* which exists had been driven from the rice fields of British Guiana by controlling the water supply (see Section 17.8). This is one step more towards what I suggested in 1910, in a public lecture given in Kuala Lumpur, in the following words:[1]

> But when we came to work out the Anophelines, it was found that different species were found in the middle of the swamp from those on the hills. Nature has, therefore, carried out a great experiment. There were three groups of Anophelines: one on the hills, one on the rice fields close to the hills, and a third lot in Krian, far from the hills. Now why do these vary? Clearly on account of something in the water; and it can easily be imagined that only a small change would assimilate the Bukit Gantang water to that of the Krian rice fields, and then malaria would disappear from Bukit Gantang too. I believe that in this way a great anti-malaria method will be evolved, and I can look to the time when we will be able to play with species of *Anopheles*, say to some 'Go' and to others 'Come,' and to abolish malaria with great ease, perhaps at hardly any expense. Drainage schemes

[1] Report in *Malay Mail*, 21st June 1910

> may become things of the past, and future generations may smile to think of how their ancestors, who thought they were so clever, burned the house to cook the pig.

A solution of the problem of hill-land malaria on biological lines has been steadily sought for, and when Dr Strickland was appointed as travelling entomologist, I suggested the following as his course of study:

> (1) Healthy, flat land (coastal belt);
>
> (2) healthy wet land (Krian rice fields); and
>
> (3) then working up from the coast into the valleys of Negri Sembilan, from what I believe healthy into what is unhealthy.
>
> There is much to be learned here, I'm sure, for the undrained swamps in valleys are certainly in many places healthier than those which are clean-weeded. Why this should be is clearly an important question. ... The above seems to me the main line of research he should pursue.

3.4 Water supplies in the Federated Malay States

Almost all the towns in the Federated Malay States have good water supplies, usually obtained by impounding streams in the jungle. But in rural districts water is obtained only from surface wells, which are very liable to pollution. With the rapid increase in the population on estates, the danger of disaster from cholera became greater each year, while, subsequent to improved drainage, the supply of water from the wells on the coast land became less and less.

3.4.1 The Coast Water Scheme. About 1907 it was apparent to the planters of the Kapar district that a better or more plentiful supply would have to be provided, and they approached the Government with the suggestion that a survey be made to ascertain if a good water were obtainable. The Government met the request in a sympathetic spirit, and after a careful survey of the streams in the hill land behind the estates, they found one which fulfilled the requirements. A complete water scheme was then drawn up, and submitted to the estates, who agreed to pay a rate which would give 4 percent interest on the capital and annual cost of the whole scheme. Work was begun in 1910, and towards the end of 1912 water was on the estates. The details of the scheme are summarised in Table 3.2.

As there is abundance of water, the scheme is to be extended to supply other estates farther north.

This is the only scheme for a rural district as yet completed; another is under consideration.

3.4.2 Private Schemes. On estates where there are hills, good water can usually be obtained from springs, and a large number of estates have now excellent water supplies laid on to the coolie lines. One of the best of these is on Bukit Rajah Estate. Spring water, collected in a large reservoir situated at the foot of a hill, is pumped up to another hill, from which it is distributed by gravitation. Another excellent supply is on Seafield Estate, where the water is passed through a Jewell filter before being distributed.

Table 3.2 The Kapar District Coast Water Scheme

Catchment area	2200 acres approximately
Surface area of reservoir	150 acres approximately
Area of estates within the scheme	37,105 acres
Area of estates using the water	23,369 acres
Original cost of scheme	$585,211.43
Annual cost of maintenance, approx.	$ 14,000
Consumption of water—Estates	8,000,000 gallons per month
Consumption of water—Railways and others	1,600,000 gallons per month

3.4.3 Surface Wells. For the protection of isolated wells many suggestions have been made, but most of these overlooked the fact that such wells were liable to become suddenly, for some unknown reason, quite undrinkable. Heavy expenditure, such as bricking them, was not only useless, but was a very frequent cause of their becoming useless. I suggested, therefore, that these wells should be fenced, and the water drawn from them by pumps.

3.5 Rules for Sanitation on Estates

Such rules were drawn up a few years ago. On some estates these rules are strictly enforced by managers; on others there is much room for improvement. They were as follows:

RULES FOR ESTATE SANITATION

Prepared by Dr Malcolm Watson and approved by the Principal Medical Officer of the Federated Malay States, by the Planters' Association of Malaya, and by the Council of the Rubber Growers' Association (Incorporated).

It has been established beyond doubt that the most troublesome mosquitoes breed mainly in stagnant water in tins and other receptacles. Such mosquitoes, although they do not carry malaria, carry other diseases, such as elephantiasis (filaria), and are thus a danger as well as a discomfort. For this reason all receptacles capable of holding water should be buried as stated in the rules.

The Federated Malay States estates are at present almost entirely free from cholera and typhoid (or enteric) fever and plague, but the rapidly growing population greatly increases the risk of these diseases becoming established. Pure water supplies, clean dwellings, and clean surroundings will prevent these diseases, which are a danger to European and native alike. Attention to the following rules by the managers of estates is, therefore, a duty to themselves, to their labourers, to their estates, and to the community.

WELLS

Drinking—Bathing

(1) When drinking water is procured from wells, such wells should not be dug within a distance of 100 ft. from the coolie lines, residences, latrines, or washing places.

(2) These wells should be separated from coolie lines, residences, latrines, and washing-places, by a drain dug (not less than 15 ft. away from the well) as deep as the estate drains in the vicinity, and called the intercepting drain.

(3) Wells should be provided with a pump placed at least 15 ft. from the well. When possible, it is preferable to place the pump on the opposite side of the intercepting drain from the well.

(4) Waste water from the pump should be collected and led to the intercepting drain. This is best effected by a small apron of ferro concrete, 3 ft. square, below the pump, draining into half channel pipes leading to the intercepting drain. Should it be necessary to discontinue the use of a well, the pump, apron, and half channel pipes can easily be removed and fitted up at the new well.

(5) Wells must be fenced so that no one can walk within 15 ft. of them; nor should it be possible for coolies to dip buckets into them.

On Hill Land

The head of a ravine should be reserved for the water supply. The head of the ravine should be fenced in. These precautions will ensure that no pollution can be washed into the well.

Well Water Dangerous

Shallow or surface wells are those above the first impervious stratum, which may be 100 ft. below the surface of the ground. Such wells are the most dangerous possible water supply. They are liable to gross pollution in three ways. (a) Contaminated buckets may be dipped into them. (b) Water polluted by clothing, washing, and bathing may run back into them. (c) Underground water passages, which are often very abundant, may bring pollution from a considerable distance, both in wet and in dry weather.

A large labour force should not depend on surface wells if a safer supply can be obtained. On hill land, permanent safe water supplies can be got from unopened ravines.

Scavenging

(1) A distance of 200 ft. around lines should be marked out by white posts.

(2) No empty bottles, tins, or any other rubbish should be deposited or buried within this area.

(3) All rubbish and refuse should be buried daily by the sweepers. Dustbins should be provided.

Latrines and Night Soil

(1) Latrines should not be situated within 100 ft. of lines unless there is a waterborne system of sewage.

(2) If trenches or pits are used, lime or earth should be applied twice daily in sufficient quantity to prevent nuisance, and completely cover excreta.

(3) Any night soil deposited elsewhere than in a latrine and near to the lines should be buried by a sweeper.

Night soil often contains the germs of cholera, typhoid fever, dysentery, and diarrhea. Flies, fowls, and dogs may spread these diseases if night soil is exposed on the ground.

Sweepers

There should not be less than one sweeper to three sets of lines.

Drains

(1) Brick drains simply pointed with cement are difficult to clean. It is much better to render the drain with cement, or use an earthenware half channel pipe.

(2) The end of the drain should be carried at least 15 ft. from the lines, and if possible should discharge into an estate drain.

(3) The sweepings of the drain should not be allowed to lie at the end of the drain, but should be buried daily when the drain is swept.

(4) Where soil becomes polluted and filthy at the end of a drain, ashes from the coolies' fires should be applied.

LINES

Provision for cooking without exposure to rain should be made by (a) raising the lines 6 ft. from the ground, or (b) having a 10-ft. verandah, or (c) by kitchen in front of the lines.

If there is only a 6-ft. verandah in which to cook, the coolie must close it to protect himself from the weather. When verandahs are shut up, the rooms become dark. Darkness leads to dirt.

Clothing and food become polluted in dirty places, and then dysentery, diarrhea, and other diseases occur.

Lines should be lime-washed every three months, both inside and outside, especially inside.

Managers should keep a watch over the food supplies of a labour force. Underfed coolies are certain to fall an easy prey to malaria or any other prevailing disease. A well-nourished gang of men are frequently seen to be healthy when others in the near neighbourhood are attacked with illness.

Inspection of Lines

Lines should be inspected daily by a European or other responsible member of the staff in addition to being visited by a dresser. Coolies not at work or complaining of sickness can then be seen and sent to hospital if necessary.

3.6 Beri-Beri

Ten years ago the origin of the disease was admittedly an unsolved problem,[1] of which, moreover, all the possible solutions seemed to have been definitely disproved. In particular it was held by those of most authority in tropical diseases, that the cause to which it is now correctly attributed had been put, by the very definite and categorical evidence of direct experiment, entirely out of court. But truth is hard to strangle, and today the result is accepted, that a malady which appeared to have all the marks of an infection,

[1] "On some of the Results of Measures taken against Beri-beri in British Malaya," by Braddon, *Trans. XVIIth Inter. Cong. of Medicine*, London, 1913.

which produced devastating epidemics, more destructive because more persistent even than the plague, is due to nothing more than an apparently insignificant error of diet. To those who know how, like a pestilence, beri-beri disabled, and by its ravages even exterminated whole communities, it must rightly appear one of the most remarkable and beneficent triumphs of medicine that its onset may be prevented and its damages repaired by nothing more recondite than the change of one solitary article of food, in fact by the mere substitution of one commercial variety of rice for another.

How the truth [about beri-beri] was discovered is one of the most fascinating stories in medicine, and if I give only a short account of it here, it is only because even the briefest account cannot rob it of its interest and the lesson it contains.

In 1890 Eijkman discovered that fowls suffered from a disease very similar to beri-beri if fed on a rice from which the pericarp had been removed, and that restoration of the same pericarp cured them. This led to an important commission of inquiry, presided over by Vorderman in 1898, which produced ample evidence to show that the incidence of the disease did vary with the sort of rice used; but effect was denied the result, owing to Vorderman's conclusion that the facts did not explain "the infectiousness of the disorder." No incontrovertible evidence of the dependence of human beri-beri on any specific difference in food had been produced, and "with the rising tide of bacteriology all interest in this side of the question seems to have become lost,[1] and the valuable results of Eijkman in particular became for a time submerged." But "the claims of almost innumerable bacteriologists, from Pekelharing and Winkler down to Hamilton Wright and Dangerfield, to have isolated an infective causal microbe, may be dismissed as one and all inglorious failures."

In 1893 Braddon noted "the peculiar exemption of the natives of Southern India (Tamil coolies) from beri-beri when immigrant into the very worst foci of beri-beri in the Malay States," while "their sickness rate from all other causes exceeded that of all the other classes of natives beside whom they lived, and with whom they were equally exposed to the incidence of all supportable infective agencies." At that time Braddon had no knowledge of Eijkman's observations, and was influenced by the current views which entirely discredited the idea that there could be any connection between rice and beri-beri. Gradually, however, the evidence accumulated to show that there was a definite connection between the two; and in 1901 he submitted evidence to a Congress of Medical Officers of the Federated Malay States strongly indicating that the freedom of the Tamils from beri-beri was due to their use of a particular kind of rice, which he called "cured" rice. This paper and a subsequent one produced the hot controversy without which progress towards the truth would be much slower than it is; and in 1904 Braddon was in a position to publish a large volume of evidence in favour of his rice theory, and to show that all the observations brought forward by his opponents fell into line with his own theory. But for the controversy many of these observations would never have been made; having been made, they helped to establish the truth.

In the face of all the facts now showing a connection between rice and beri-beri, medical opinion in the Federated Malay States had to be revised; and Government gave facilities for Braddon, in association with Drs Fraser and Stanton, to conduct an

[1] *Ibid.*

important experiment on free Javanese coolies, who were engaged in road construction. The result was a further striking proof of Braddon's theory that cured rice with the pericarp was a preventive of beri-beri, and a cure for the disease, if not present in too advanced a stage. For all practical purposes the cause of beri-beri was known; we had also learned how it could be completely prevented. There remained still to be discovered what was the exact substance in the pericarp which meant so much to the rice eater. In their laboratory, Fraser and Stanton, by experimenting on fowls as Eijkman had done, established the fact that a dangerous rice might be known by the small percentage of phosphorus pentoxide it contained; but they also pointed out that the phosphorus was not the important substance; it was only an indicator. The exact substance they have been unable to isolate; nor have any others [been able to do so]: it seems to be closely allied in chemical composition to—the will-o'-the-wisp.

One would have thought that the stamping out of beri-beri was now quite a simple task: if the dangerous rice were stopped, the disease must disappear. But unfortunately the dangerous rice is white in colour, whereas rice with its pericarp is brownish or red; and as the Chinese have learned to associate whiteness with purity, the sudden stoppage of the dangerous rice would lead to civil strife. Many suggestions to overcome the difficulty have been made; but it appears to me that, by the use of Fraser and Stanton's indicator, the way out of the difficulty will be found. I suggest that gradually, and over a long period of years, the standard of phosphorus in white rice demanded by Government be raised each year or each two years; the Government should notify to millers and importers that, before rice manufactured in the country or imported can be sold, it must contain a certain percentage of phosphorus. In this way the change would come about so slowly that no one would notice it; unconsciously the people would be educated, and a new generation would arise that knew not the dangerous beri-beri rice.

4. Quinine prophylaxis in Italy

4.1 Distribution of Malaria in Italy

As our knowledge of malaria in the Malay States became more clearly focused, it was apparent that its distribution was very different from what had been found in other countries, in Italy, for example. The existence of malaria in large tracts of that country had led to its study, and the subject was one of much more than purely scientific interest. Its profound economic importance pressed persistently for solution. In all countries the alluvial plains are the richest agricultural land; they are Nature's great factories. But in Italy in the summer and autumn, when the factory was capable of working at its highest speed, the wheels were still; the land was deserted. Malaria had made the plains almost uninhabitable; and perhaps in no other country in the world had the disease been so carefully studied. And so notable had been the contributions to the knowledge of malaria made by the Italians, that the general ideas of the disease found in the textbooks of other countries have been largely cast in the mould of Italian experience.

The Italians had established quite beyond dispute that the hills were healthy even when the plains only a few feet below were intensely malarious. And it was from the knowledge of this fact that the authors of books on tropical sanitation advised people to build their dwelling houses on high, dry situations, "avoiding a clay soil if possible." – "As high ground as possible, is a golden rule for a camp." – "Against the vertical uprising of malaria, elevation, however small, affords some protection." In Italy, too, the association of malaria with swamps was no mere school-man's theory. It was something so real to thousands that it had woven itself into the texture of their daily lives. Year by year, as the summer months came round, thousands left the plains each evening and slept in the hills, to return in the morning to their daily task. To spend a night in the plains was only to court the disease; and the lesson had been taught too often by bitter experience to be unknown even to the most ignorant. The distribution of the disease was indeed so peculiar, that men much less acute than the leaders of medicine in Italy could not fail to mark it.

When we search for the explanation of the freedom from malaria of the Italian hills, we at once find it in the habits of the local *Anopheles.* In Italy the only mosquitoes that carry malaria live in swamps, pools, and very sluggish drains overgrown with vegetation. From the drains they disappear when these are freed from vegetation, or when the current reaches a certain velocity. In Italy, unlike the Malay States, no *Anopheles* are to be found in the hill streams; and so in Italy, no malaria is to be found in the hills. While, then, it is a golden rule for Italians to avoid the plains and live in the hills, the rule does

not apply to Malaya; nor, as we shall see, to many parts of Asia, where the distribution of malaria is different from what it is in Italy, since the Anopheline fauna have different habits.

4.2 Physical Conditions Favouring Malaria

Italy consists of the high lands of the Apennines, and a stretch of flat land from the hills to the sea. In the flat lands or plains there is little "fall," and the waters find the sea with difficulty. Dashing down the hills laden with detritus, the rivers soon reach the plain. Now no longer able to carry their burden, where the current slackens they throw it down, and sometimes the bed of the river is above the level of the land through which it flows, and over which it would flood but for the confining banks made by man.

The sea, too, seems to have joined in the conspiracy to swamp the land. Practically tideless, the sea for ever holds up the rivers as they seek to empty themselves, and it dams them back in stagnation for miles. Were the sea but to recede three or four feet even for a few hours in the twenty-four, it would stir the rivers to life. It is the stagnation that brings malaria and death. And not content with this sullen grip of the river's life, from time to time in the paroxysm of its storms the sea throws barriers of sand along the shore, and across the river, as if trying to shut it up completely. Sometimes the river bursts through these bonds; more often, winding along the coast behind the sand dunes, after a long detour it reaches the sea. But in its course it has become a swamp rather than a well-defined river. This is the cause of many marshes along the coast of Italy, not the least well-known of which are the Pontine Marshes.

The physical conditions favour the creation of these marshes along the coast; and malaria was so prevalent in the Italian littoral that the Tuscan school formulated the theory that malaria was due to a mixture of fresh and salt water. A map of the marshes of Italy was indeed a map of its malaria; and not only were the Italians aware of the direct connection between swamps and malaria, but they were aware—they had proved it hundreds of times—that the thorough drainage of swamps had freed portions of the land from the pestilence. Rome itself was an example of the beneficent result of drainage. Yet with the physical conditions just described, it will be seen that drainage generally along the coast presented the greatest difficulty, and we can readily understand why the Italians often abandoned the attempt. The project would have appealed probably more to those great engineers, the Dutch.

Referring to the prevention of malaria by the destruction of mosquitoes, Celli writes:[1]

> Nevertheless, to the old and reliable methods of the campaign against malaria, namely, draining and agrarian sanitation, our efforts were directed.
>
> The hygienic effects of the sanitation by drainage already carried out were studied. The result was that on large extensions of land the best drainage sanitation very frequently failed to drain off all the water or to give it sufficient velocity to impede the aquatic life of *Anopheles*. Frequently also the deficiency or the neglected state of the complementary drains and the discharging canals helped to maintain the anophelism.

[1] *The Prevention of Malaria*, by Ross, p. 412.

4.3 Experience with quinine

It was mainly, then, on account of the difficulty of draining many parts of Italy that Celli so strongly advocated the use of quinine, and the drug was widely distributed by the State, with the result that the number of deaths from malaria in Italy has been greatly reduced; but in many respects their experience with the drug has been identical with that in the Malay States. Celli, indeed, writes of it:[1]

> We have proved over and over again that some fevers are pertinacious in recurring in spite of the abundant and protracted use of quinine, either alone or in association with the so-called re-constituents (iron and arsenic). … It follows from this that even the best treatments in the pre-epidemic period do not succeed in preventing, as Koch thought they would, the development of malaria in the following summer.
>
> Therefore by the quinine treatment alone, to exterminate malaria from an extensive locality is much more difficult than one would imagine. In any case it must be a work of long duration; that is to say, treating, in every period of the year, day by day, energetically and assiduously every case of malarial fever.

Commenting on this in 1909, I wrote:[2]

> To me it seems only the vision of a dream that any organization will ever induce a whole tropical population to take quinine in doses required by the Italians. And when it is further considered that the population, even when taking quinine, would still be infectious, the policy of spending money on quinine for an indigenous population where drainage is physically possible appears to me indefensible, either on medical or financial grounds.

4.4 Report to the Superior Council of Health

As the discovery of the best method of eradicating malaria was the most important medical question in Italy, a strong and representative Commission investigated the whole subject, and presented a report to the Superior Council of Health in 1910. A summary of this report appeared in the August number of the *Monthly Bulletin of the Paris International Public Health Office*, and has been translated [3] by Major N. P. O'Gorman Lalor of the Indian Medical Service. The Commission found that "great progress" had been made in treating the sick. "The treatment of malaria has everywhere advanced by leaps and bounds. The laws in force against malaria have created an excellent social prophylaxis by placing quinine at the disposal of all, and have thus made it possible for the sick to be treated from the outset of the disease." They also found that "it is absolutely certain that malaria has undergone notable diminution in places where the windows of dwelling houses have been provided with wire gauze mesh to prevent the entry of mosquitoes. Nevertheless the experience of former years shows the grave difficulties which the application of this measure has encountered."

The Commission consider that it is better to petrolise pools and marshes than trust to larva-destroying fish, with which experiments had been made. But while advocating the use of quinine for the sick, the Commission condemn the wholesale issue of quinine to healthy individuals on account of (a) the wastage which the system has occasioned,

[1] *Ibid.* [2] *Ibid.*, p. 562. [3] *The Campaign against Malaria in Italy*, by Lalor, published by Thacker, Spinck, & Co., Calcutta, 1912.

and (b) the impossibility of ascertaining to what extent this prophylactic quinine is consumed. In the report they say:

> In brief we see that in Italy prophylaxis has been applied in few places, and in a very limited fashion. The administration of quinine to healthy individuals has been rather nominal than real, and if the past is to furnish an index to the future, we can say that the possibility of extending to every quarter of the kingdom the prophylactic work practised in experimental areas under the control of committees, associations, etc., is a possibility too remote from realization to be relied upon.

With this conclusion I think all who have any knowledge of the use of quinine as a prophylactic will agree. Finally the Commission point out, that only where "intensive cultivation has overspread the land" has malaria disappeared. They insist that it is not enough to cut large canals; these are necessary, of course, for without them the land cannot be cultivated at all; but of no less importance are the smaller drains and the digging over of the ground, which creates that porous soil into which rain sinks instead of forming pools on the surface of the land.

> Hydraulic reclamation constitutes an advance towards a state of more perfect hygiene, but it does not suffice, since it deals with large canals, not with the smaller and more useful ones, made by the spade of the peasant. The real work of reclamation lies in the intensive culture of tracts previously drained by the aid of hydraulic reclamation. State quinine has availed to reduce sickness and mortality from malaria, but the disease has not disappeared except in places where intensive cultivation has overspread the land. In these latter circumstances malaria is found to disappear even where the related mosquitoes have continued to infest the locality. It is necessary, then, to insist particularly upon the smaller works of reclamation so often neglected in favour of more grandiose projects which entail enormous expense and which are of less use from a health standpoint. Especially is it necessary to prevent the formation of artificial collections of water.

In other words, the better the land is drained by large and small canals, the more porous the soil becomes, and the fewer the pools in which the mosquito can breed. So the final conclusion of the Italian Commission is that the best way to eradicate malaria is to cultivate the soil—and the more thorough the cultivation the more rapidly will malaria disappear. So that after years of work along the lines of quinine prophylaxis, the Italian Commission now inclines to the conclusions we had arrived at on the other side of the world.

5. Malaria in India

While the contrast between Malaya and Italy was very marked, no less striking was the parallel noticeable between my observations in Malaya and those recorded in the admirable reports of the Commissioners to the Royal Society published in 1902, and by later observers elsewhere. From these it was evident that intense malaria was often found in the hills, while the plains were not necessarily malarious, as the following extracts will show.

In 1909, in a letter to the *Lancet*, Major S. P. James and Captain Christopher write:

> We are aware that India as a whole is not intensely malarious. There are wide tracts of country where the disease though present is not markedly interfering with the prosperity and natural increase of the population. In such areas action for the reduction of the prevalence of malaria is unnecessary; the disease is sufficiently dealt with by general arrangements, such as are taken for the mitigation of other diseases. Secondly, there are areas where malaria is constantly present to a moderately intense degree; and, thirdly, there are areas in which the disease can only be described as decimating the people, and converting once populous and prosperous districts into scantily peopled and decayed ones.

In the sixth report of the Commissioners of the Malaria Committee of the Royal Society, published in 1902, a map will be found showing the malaria index of Bengal. The report says:

> The following map and table will at once show how in proceeding from Calcutta northwards till the foot of the Himalayas was reached—a distance of some 300 miles—we passed from a region the endemic index of which was 0.0 percent, through regions with increase in indices of endemicity, till at the foot of the hills, in a district known as the Duars, a very high degree of infection was reached, 40 percent to 72 percent, as high indeed as that found by us in West Africa. We have, then, in a region not above 300 miles in latitude, subject to almost identical climatic influences, an endemic index varying from 0.0 percent to 72 percent.

Commenting on this, I wrote:[1]

> If we take a map of the Klang district from the sea to the hills we find that malaria may be represented on, say, an estate on the Kapar Road by a spleen index of nil; passing inwards we find perhaps an increased index due to proximity to jungle. Once, however, we reach the first of the hills, even of the small hills, of the Peninsula the spleen rate rises to from

[1] *Prevention of Malaria in the Federated Malay States*, p. 123.

> 70 to 100, and the most intense malaria is met with, due to an Anopheline which breeds in hill streams. The distance from the place with the spleen rate nil to that with a spleen rate of 100 is about 3 miles. The climate of the two places is the same.
>
> It is impossible to look at these two maps without the idea at once springing to the mind that the similarity is more than a coincidence. We find that the malaria in both is highest when we reach the hills, and that the carrier of malaria in the hill land of both is an Anopheline which breeds in the hill streams.
>
> In both, when we reach the plains another Anopheline is the carrier. Malaria is much less intense, and may even be entirely absent. Is it too much to believe that our observations in the Malay Peninsula give the key to the malaria of India?
>
> In the Malay Peninsula in the short span of one generation the country has been reclaimed in considerable areas from absolute jungle.
>
> We see that when first inhabited the plains or flat land are no less unhealthy than the hills, but when the land has been drained and cultivated it becomes much less malarious. We can actually see the process going on under our eyes in Malaya.
>
> I suggest that the map and our knowledge of Indian malaria indicates that what is occurring here now occurred in India in the past. Only in India everything has been on a more extensive scale. In Malaya the space is 3 miles, and the time one generation; while in India the space is 300 miles, and the time perhaps 300 generations. History does not tell us when first the Indian plains were cultivated.
>
> And, if this be so, is it too much to believe that what freed the greater part of the plains from malaria will free the remainder; that the small foci remaining on the plains will yield at once to properly devised and probably inexpensive operations, which at the same time will appreciate he value of the land?

Referring to the areas of intense malaria where the population is decimated, the [Indian] writers continued:

> It is upon such areas as the last—where malaria is present in intensified and epidemic form, and is acting as a pestilence—that attention should first be concentrated. Such epidemics have causes which can be traced, and even at present it is known that the factor of *Anopheles* mosquitoes is only one of many that are concerned in bringing about the epidemic result. In the great industrial centres, for example, we have malarial epidemics whose immediate cause is the immigration under special conditions of non-immune people from healthy districts to foci of malaria started by this very process of immigration. We need not here describe the events and conditions that are concerned in causing epidemics of malaria in such centres, nor need we mention other examples in which recent work has revealed what are the really important factors concerned. It suffices if we emphasise the fact that the prevalence of *Anopheles*, though always important, is by no means in every case the most important factor to be considered.

The great industrial centres to which the writers allude are the tea plantations of Assam, etc., and we find their parallel in Malaya in the rubber estates of the hilly land. In both there is "the immigration under special conditions of non-immune people to foci of malaria." In both there is the most intense malaria.

The Indian writers had been greatly impressed, and very properly impressed, with the severity of the outbreaks which follow the introduction of non-immune people to

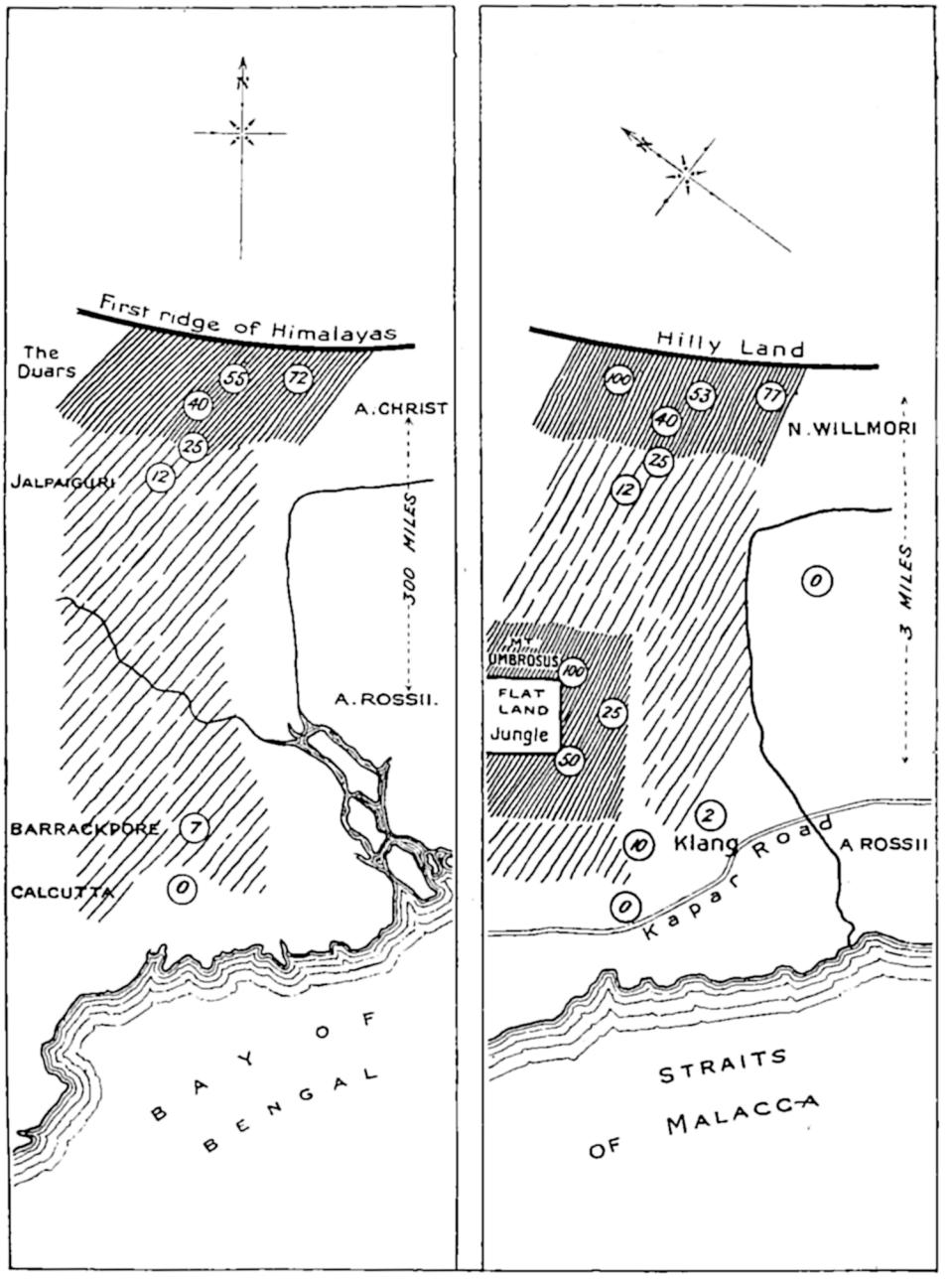


Figure 5.1 Sketch map to show variation of endemicity in Bengal and in District of Klang, Federated Malay States

areas where malaria-carrying *Anopheles* exist. In an able paper[1] they had shown how the coolie camps of the great engineering works had ever been foci of terrible epidemics, or, as they called it, a hyper-epidemic of the disease. Of the importance of this factor in the production of epidemics, I have already written, and am in accord. But having had the good fortune to witness similar immigration to estates, and to public works where the Anopheline factor was absent, and having noticed the absence of the outbreaks when the mosquito was absent, I suggested the Anopheline as the more important factor, as follows:

> But in Malaya the same immigration of the very same people (indeed, where coolies are transferred from one estate to another, of the very identical individuals), occurs to flat land and hilly land estates equally; but it is only on the hilly places that malaria occurs, while on the flat land estates where the coolies are housed half a mile from jungle, malaria is practically unknown, and the spleen rate is nil. If these be facts in Malaya, I would suggest that the Anopheline is the important factor in the areas of intense malaria in India, as I consider it is in Malaya.

The parallel which I suggested in 1909 was, however, to be closer than I suspected, both in respect to the plains and the hills.

In preparing the map of Klang for comparison with that of Bengal, I had added an inset on the plains, and called it “Flat Land Jungle." Referring to this, the editor of *Paludism*[2] pointed out that Stewart and Proctor had demonstrated that in villages near to jungle in Lower Bengal the spleen rate was high, just as in Malaya, and that the inset marked by me “Flat Land Jungle” in the map of Malaya might be inserted in the Indian map, so making the parallel I had suggested complete in every respect. In his opening address[3] the Hon. Surgeon-General Sir Pardey Lukis, Director-General, Indian Medical Service, said:

> All the schemes I have mentioned so far are for urban districts only, but you must not imagine that the very important question of malaria in rural areas has been neglected; on the contrary it has our most earnest attention, and in this connection I must allude to the excellent work done by Stewart and Proctor in Lower Bengal. They have shown that a close connection exists between over-vegetation and intensity of malaria—in which respect they are in close agreement with the findings of Watson of Malaya. At the suggestion of the Government of India, the Government of Bengal has taken up the matter, and it is proposed to allot a considerable sum of money to carrying out an extensive experiment of jungle clearing in the neighbourhood of inhabited areas. Should this experiment prove a success, we shall have at our disposal one method at least of improving the conditions obtaining in small villages, especially in the deltaic area. But although his method is likely to be useful in flat country, it is doubtful whether it will avail in hilly tracts, especially in hilly tracts intersected by ravines. Watson has found it useless in Malaya, and Kendrick has arrived at similar conclusions in the Central Provinces. Major Perry, too, in his paper which is for discussion today, goes carefully into the practical question of jungle clearing in the hilly tracts of the Presidency, and shows that whereas on the 3000 feet plateau jungle clearing produces little obvious effect, on the 2000 feet plateau the conditions

[1] “The Human Factor in Malaria,” *Trans. of the Bombay Medical Congress*, 1909. [2] *Paludism*, No. 5. [3] *Proceedings of the Third Meeting of the General Malaria Committee*, held at Madras, 1912.

are different, and the proper clearing of jungle gives hope of the practical eradication of malaria.

5.1 The Identification of *Anopheles maculatus*

Turning now to the parallel of the hills again, we find it closer than was originally suspected. In Malaya we had identified the stream-breeding *Anopheles* as *A. willmori*. *A. maculatus* had been recorded by Mr Theobald as among the specimens sent to the British Museum from the Federated Malay States, but neither Dr Leicester nor I had ever caught a specimen. In his monograph on *The Culicidae of Malaya*, Dr Leicester states, when writing of *A. willmori*:

> This mosquito evidently bears a strong resemblance to *A. maculatus*, specimens of which have been taken in Taiping. It differs, however, in the banding of the palpi. A drawing of the palpi of *maculatus* is given in Theobald's monograph, and shows three white bands at the apex instead of two equal bands present in *willmori*.

With not only a written description, but with a drawing before us, demonstrating the difference between Theobald's *maculatus* and our Malay species, we were satisfied that the mosquito with which we had to deal was not *A. maculatus* but *A. willmori*. When making a visit to Japan in 1911, I was therefore much interested to see what *Anopheles* was responsible for the malaria in Hong Kong. The three species there had been identified as *A. rossii*, *A. sinensis*, and *A. maculatus* as far back as 1901, by Major James, when passing through Hong Kong with troops sent from India to the Boxer Rising.

In the collection at Hong Kong there were two specimens labelled *A. maculatus*, and on examination I recognised them as identical with what we called *A. willmori*. But, as I pointed out, they differed from Theobald's description of *A. maculatus* in having three palpal bands and not four.

The next step in the discovery of the real identity of the mosquito took place when in 1911 Major S. P. James visited the Federated Malay States when conducting his inquiry on behalf of the Indian Government on the distribution of *Stegomyia fasciata* (*Aedes calopus*), and the probability of yellow fever reaching Asia after the opening of the Panama Canal. Major James had fortunately brought with him a fine collection of Indian mosquitoes, and he showed that our *A. willmori* was identical with the Indian *A. maculatus*; that *A. maculatus* had only three palpal bands, not four as described by Theobald; and he suggested that since specimens of *A. maculatus* had occasionally four bands, Theobald might have got one of these for his type specimen.

Finally, when Dr A. T. Stanton was in England, the specimens in the British Museum were re-examined and he writes:

> The nomenclature of this and closely allied species has given rise to more difficulties than any other Oriental *Anopheles*. An examination of the types of *Anopheles maculatus*, Theobald, has revealed a reason for the confusion that has existed in the minds of Eastern workers as to the characters of these species. The types are not male and female of the same species, but represent two distinct species, the male being known to Eastern workers as *maculatus* and the female of the species known to them as *karwari*.

In view of the profound economic importance of the insect which lives in the hill streams of Malaya, it was of great importance to other countries to have its identity properly established. Its presence or absence in other countries could be definitely ascertained, and measures found useful in Malaya could be adopted if necessary.

5.2 The Duars

Early in 1913, in re-reading series No. VII. of the Reports of the Malaria Commissioners to the Royal Society, I observed the small footnote on p. 37: "In Report VI. *A. metaboles* was throughout erroneously printed for *A. maculatus*." *A. maculatus* by this time proved to be identical with our *A. willmori* in the Federated Malay States, and had a new interest for me, and turning back to Report VI. I found it referred to a mosquito found in the Duars. "The district known as the Duars is a strip of land extending for some hundreds of miles along the foot of the Himalayas. It is a gently sloping tract of from 800 ft. to 1200 ft. above the sea, and abounding in small streams."

In the Duars the Commissioners found three *Anopheles*, namely: *A. rossii*, *A. christophersi*, and *A. maculatus*. From experiments, and from the fact that the spleen rate in Calcutta was 0, although *A. rossii* abounded, they concluded it was not a carrier of malaria.

Of *A. christophersi*, however, they say (p. 10): "This species is undoubtedly a good carrier. Sporozoites were found in four out of sixty-four specimens, or 6.25 percent. ... *A. metaboles* [*A. maculatus*].—From the difficulty of obtaining the adult insects, sufficient numbers were not examined to determine whether this species carried malaria. Eleven specimens from huts were negative" (p. 10)." – "*A. metaboles* [*A. maculatus*] was in the Duars also a very common mosquito, judging by the large numbers and wide distribution of larvae" (p. 8).

Referring to their breeding place, the report says (p. 19): "*A. christophersi*: in the Duars this species breeds in sluggish streams with grassy edges. It was never found by us in puddles in the coolie lines, or in small ponds, roads, paths, etc. In some cases larvae were dipped up from water running with considerable velocity, but always among the grass at the edge." Of *A. metaboles*: "The larvae of this species also occur in streams more or less rapid. They are also abundant in swampy tracts by the side of streams, in rice fields, and small pools. They are not found in the small foul pools in the coolie lines. They occur at a height of 5000 ft. This species has been found by us at very considerable distances from habitations."

It will be seen from these extracts that *A. metaboles* (*maculatus*) in the Duars was found in much the same situations as it is found in the Federated Malay States, that is, in small streams in the hills. Although not actually convicted of carrying malaria in India, there is little doubt that this was simply due to the difficulty the Commissioners had in catching adult insects.

There is some evidence, however, in the report to show the possibility of *A. maculatus* being even more important than *A. christophersi*. "At Sam Sing (3000 ft.), Bengal Duars, this species *A. metaboles* (*maculatus*), was found alone and associated with an endemic index of 25."[1] It appears, too, that "*A. christophersi* was only found by us in the

[1] Report VII., p. 37.

Duars district, and it was not found above a height of about 1000 feet."[1] *A. metaboles*, on the contrary, had a wider range, and "occurred in small numbers as one approached the foot of the hills. It was the commonest *Anopheles* in the upper portion of the Duars and lower hills. It occurred also at an elevation of nearly 5000 feet near Kurseong."[2]

5.3 Jeypore Agency, Madras

Subsequently the Commissioners went to the Jeypore district, and were at once struck by the fact that "the *Anopheles* fauna of the Duars and the Jeypore hills, two regions of intense endemicity, is almost identical."[3] And just as on passing from the swampy plains of Bengal to the Duars, they had passed from regions of low to regions of high spleen rates, and had been struck by the contrast, they note in Jeypore Agency, Madras "a striking contrast which occurred between the high endemic index of the hill regions and the low index of the adjacent plain district."[4]

They record that *A. maculatus* is not found on the plains of Bengal, and that since leaving the Duars they had not encountered it, until they reached the Jeypore hills.[5] In view of our experience in the Federated Malay States of the importance of this mosquito, it is significant to find among their conclusions "that in the two regions of intense malaria visited by us (Duars and Jeypore hills), black water fever is well known and has attacked a large proportion of the resident Europeans."[6]

I do not wish to press unduly the importance of *A. maculatus* as against *A. christophersi*; for one stream-breeder would be as bad as another, provided both were equally common and were equally suitable for the sexual stage of the parasite's life. It does not, however, appear to me from reading the reports that the two mosquitoes are quite alike. *A. christophersi* appears to live only under an elevation of 1000 feet, and although found in running water, the larvae "were always amongst the grass at the edges." In Malaya *A. albirostris* and *A. karwari* live in grassy streams, and thus show a resemblance to *A. christophersi*, but are certainly not so important as *A. maculatus*. *A. maculatus* has a wider range of elevation than *A. christophersi* in India, and our experience in the Federated Malay States suggests that it may not be confined only to grassy streams. The point is worth further investigation. I may be quite wrong in my suggestion. I would, however, emphasise that *A. maculatus* does exist in hill streams in India, and that measures inimical to *A. maculatus* would be equally inimical to *A. christophersi* and *A. jeyporensis*.

5.4 Ckota Nagpur

Finally, before leaving the subject of malaria in India, I would draw attention to some points in Major Fry's *First Report on Malaria in Bengal.* Unfortunately he was unable to identify the carrier of malaria either in the plains of Bengal or in Chota Nagpur. But in the latter division he gives a table showing the distribution of malaria in passing from the plains up to the plateau and then to the higher ranges. He describes these regions as follows:

[1] *Ibid.*, p. 14. [2] *Ibid.* [3] *Ibid.*, p. 37. [4] *Ibid.*, p. 24. [5] *Ibid.*, p. 37. [6] *Ibid.*, p. 45.

Table 5.1 Summary of findings by Major Fry on spleen rates in different regions of Bengal

Region sampled		Number of children examined	Spleen rate
I	Seven villages of the plains	137	1.6
II	Seven villages at the foot of the Ghats	109	88.4
III	Fifteen villages on the plateau (elevation 2000 feet)	528	7.0
IV	Four villages on Northern Ghats	78	37

(1) The more or less flat plains of Manbhum, with a porous soil, and hot, dry climate. Rice, however, is grown, and the "crop entirely depends on rainfall, which is collected and drained off from the higher levels to a series of terraced rice fields which spread fanwise down the slopes until finally the water is allowed to flow into rivers." As will be seen from Table 5.1, the spleen rate is very low.

(2) The "Terai" region, situated at the foot of the slopes from the plateau to the plains. In travelling here, "at frequent intervals one crosses small rocky hill streams which are leading down to the plains." Again, as in similar places in Malaya, there is intense malaria.

(3) The third region is the plateau itself, which covers the greater part of Chota Nagpur. This plateau has a general elevation of some 2000 feet. Here is but little malaria; while when we pass to

(4) The villages at the foot of the Ghats to the north, the malaria rate again rises.

Table 5.1 condenses the data reported by Major Fry. Unfortunately Major Fry was unable to complete his investigation, but it is impossible to resist the conclusion that, as in the Duars, in Jeypore, and in Malaya, a stream-breeding *Anopheles* is responsible for the intensity of malaria in the hill regions of Chota Nagpur. Indeed Major Fry himself suggests (p. 29) that observers visiting at a time when the floods were over would find "in these hill streams a series of pools swarming with larvae."

5.5 Ceylon

A. willmori had been reported from Ceylon, and thinking that the observers there had possibly been misled by Mr Theobald's description of *A. maculatus*, as we had been in the Federated Malay States, I asked Mr Edwards of the British Museum to re-examine the *A. willmori* in the collection of insects from Ceylon. This he was kind enough to do, and found, as I had suspected, the Ceylon insect to be in reality *A. maculatus*.

Ceylon is a country with a great mass of hills in it; but, as far as I am aware, no work has been published showing the relation of the distribution of the disease to the species of *Anopheles*.[1]

Probably the largest spleen census yet recorded has, however, been carried out in Ceylon, no less than 92,258 children having been examined. Of these, 34.05 percent had enlarged spleen, which shows that if any portions of Ceylon are healthy, others must be very unhealthy. I know from a friend that one estate at the foot of the hills suffers intensely from malaria, and I have heard that in some years malaria mounts to an altitude of 3000 ft. In view of what we have seen elsewhere, it is difficult to resist the suggestion that *A. maculatus* plays no unimportant part in the spread of malaria in Ceylon, and is probably the agent which causes it to rise to these heights in certain years.

[1] Dr Bahr has recently published a short note of the malaria and mosquitoes of Kurunegala, a town in Ceylon.

6. Notes on Sumatra

Across the Straits of Malacca from the Malay Peninsula lies the island of Sumatra, part of Netherlands India. At its nearest point it is only 35 miles from the Peninsula, and, at its northern end, it is no more than 100 miles away. Small trading stations on the coast had been occupied by both the British and the Dutch, during the past one hundred years, but only within the last fifty years has any considerable extent of the country been opened up. About the middle of last century a tobacco company—afterwards to become the great Deli Maatschappij—took up a large tract of land; and their headquarters, Medan, became the site of a fine town, and also the political and commercial capital of North-east Sumatra. Other tobacco companies followed in their wake, and subsequently large areas were planted with rubber.

Reports came to the Federated Malay States of the excellence of their hospital system, and of the low death rates of the labour forces employed on estates in Sumatra. In view of the difficulties we had met with in controlling malaria in the Federated Malay States and the high mortality from it among our labour forces, I was anxious to visit Sumatra in order to learn how it was controlled there. I also desired to ascertain if malaria was distributed as it was in the Federated Malay States, or as in Italy. Mr Rainnie, the representative of Messrs Harrisons and Crossfield, Ltd., in the Federated Malay States, kindly gave me a letter of introduction to Mr Mathewson, their representative in Medan, and through his kindness I was able to see a considerable part of the country, and meet those who gave me much help.

My stay in Sumatra was, however, of a very limited duration, and that the reader may form a proper estimate of the value of my views and observations, I propose to record what I saw much in the form in which it exists in my journal. In this way the value of any statements made may be gauged; and at the same time observations may be recorded, the full significance of which may be grasped by others, although perhaps appreciated only in part by myself.

6.1 Travel to Sumatra

6.1.1 Belawan. Leaving Penang about midday on the 3rd of March 1913, the steamer sailed for Belawan, the port for Medan, at a leisurely pace; for it would be impossible to cross the bar at the mouth of the river until about 8 a.m. on the following morning. The coast is low-lying as in many parts of the Federated Malay States, and covered by mangrove forest. The rise and fall of the tide here is 7 feet, only half of what it is at Port Swettenham. On an island two or three miles from the mouth of the river, the

small town of Belawan forms the terminus of the railway to Medan. The construction of this port, as at Port Swettenham, and the building of the bridge connecting the island with the mainland, had been the occasion for a serious outbreak of malaria; and the reputation of the place is still such that all Europeans connected with the port live in Medan, coming down to Belawan by the first train in the morning, and returning by the last in the afternoon.

I was hardly surprised at its reputation. The town had been built on a mangrove swamp. The site had been made up with earth brought down by rail, and, owing to the great expense of this, the minimum amount of the mangrove swamp had been reclaimed. Although a small part of the native portion of the town had a bund round it, no attempt had been made to reclaim a large portion of the swamp by bunding and draining, as at Port Swettenham, and the mangrove grew to within a couple of chains (132 feet) of the houses. With no inducement to expand, the town consists simply of a narrow strip of raised land on the edge of the island, and at its widest part is not 10 chains across. The whole town is well within the malaria radius of the swamp.

In the brief stay I made at the port, it was impossible for me to examine the children; but, as will be recorded later, on a visit to a somewhat similar place on the edge of mangrove, I found a percentage of the children with enlarged spleen. There is good reason to believe, therefore, that Belawan deserves the reputation it has.

6.1.2 Medan. The distance from Belawan to Medan, some 20 miles, occupied an hour in the train. After leaving the station at 1 p.m. at Belawan, the train ran through the mangrove forest which covered the island, and soon reached the bridge that connects the island with the mainland. Over this the train ran at about 3 miles an hour; for, I understand, the piles of the bridge are floating in the mud; no solid bottom could be reached. The remaining part of the journey calls for no special comment. It was through kampongs, full of fine old fruit trees, and full, too, of the weeds and lalang so characteristic of native cultivation.

So far as could be ascertained from the train, the country was flat, like the alluvial flats of the Peninsula; but in reality it was not so; and Medan stands 50 feet above the level of the sea. Through Medan a small river flows, and it has cut a channel with almost vertical sides 15 to 20 feet below the general level of the ground. The current of the river at Medan is 4 or 6 miles an hour in dry weather. No water stands in the roadside ditches in and around the town. Evidently the natural drainage of this part of the country is excellent, and the ground-water is low. During my stay at Medan, I noted a general freedom from mosquitoes, and greater dryness in the air, than in the Federated Malay States. In fact this was a very pleasant feature of Medan. The town is well laid out and well looked after.

Calling on Mr Mathewson, I explained the reasons for my visit, and he arranged for me to see a considerable tract of the country. He also introduced me to Mr Van Tyn, the chief administrator of the Deli Maatschappij, who in many ways gave me assistance.

6.2 Tandjong Kassau estate

6.2.1 5th March: Medan to Tandjong Kassau. From Medan to Tandjong Kassau is 64 miles; and the road runs, roughly speaking, parallel with the sea, and from 10 to 20 miles inland. On leaving Medan the scenery was as different as possible from that of the Federated Malay States. In the Federated Malay States when the land is not under cultivation, or under lalang following the abandonment of the old tapioca clearings, it is covered by jungle, and the road is only a narrow lane cut through dense forest. But in this portion of Sumatra practically the whole country has been cleared of jungle; and on the T. Kassau road I did not see jungle until about 45 miles out of Medan.

The reason for this wholesale clearance is that a second crop of tobacco cannot be taken from the land until it has rested seven years. So the tobacco estates usually consist of 8000 acres, 1000 of which are cultivated each year. After the tobacco crop, a crop of rice is taken the following year, and the remaining six-eighths of the estate is allowed to spring up in secondary growth. A comparatively small area of cultivation of this kind is, therefore, responsible for the destruction of a large area of jungle; and country so treated is much more open than the Federated Malay States, where cultivation is on more economical lines.

On the left as we drove along, the eye traced the land gradually rising till it ran into the great range, some 4000 to 5000 feet high, which forms a backbone to Sumatra. On the cultivated portions of the estates great sheds covered by attaps (palm leaves) were prominent objects in the landscape. In these, the tobacco leaves receive a preliminary drying before being taken to the fermenting sheds at the headquarters of the estate. The only other thing that caught the eye was a clump of tall casuarinas, marking the headquarters of the estate.

We crossed many rivers, all of which were at least 6 feet and some 20 feet below the average ground level. The ground appeared on the whole to be level, only undulating where it dipped into, and then rose out of, what seemed an old river track. The soil in the sides of these old tracks was red; and that in the bottom grey. The general groundwater level, except in these tracks, must have been 25 to 30 feet below the surface. At the time of my visit the ground was very dry; and all the little streams contained dirty looking water. Often the colour was dirty white, like that in a road puddle; and before I knew anything of their actual inhabitants it occurred to me they were ideal breeding places for *A. rossii*.

In all the 64 miles I noted only one mile where a river—the Sungei Ular—had spread itself out as a swamp. Through the swamp the road ran on an embankment; and the land was too low and swampy for cultivation. When at last we came to the virgin jungle, it was seen that the land was dry, not swampy like the alluvial plains of the Federated Malay States, and that the jungle trees were of particularly fine growth, a happy omen for rubber in Sumatra when the trees have reached maturity.

6.2.2 A healthy estate: *A. maculatus* absent. My object in visiting this estate was to see how far it corresponded with a hill estate in the Federated Malay States in physical characters, and if so, whether or not malaria was present. On arrival, Mr Blick, the

Table 6.1 Patient distribution in the hospital at Tandjong Kassau, as of March 5th 1913

Patient affiliation	Number
Outside (non-contributing) estates	50
New coolies under medical observation	76
Contributing estates	445
Total	571

general manager of the Tandjong Rubber Company, kindly took me to the hospital, which is under the charge of Doctors Manchaunp and Van Wyl.

The hospital consists of a number of buildings connected by corridors. Each ward is 70 feet long by 22 feet wide, and has accommodation for forty patients. At one corner there is a room for a dresser. The walls are brick, the floors cement, and down the centre runs a shallow drain. There is no verandah. The windows are covered by mosquito-proof screening fixed so that it cannot be removed. On the inside the screening is protected by ordinary half-inch mesh iron-wire netting. The disadvantage of this is that the screening cannot be easily cleaned. The jack-roof was also screened. So were the double doors, where, however, the screening had been partially destroyed by rust, evidently from water used in washing the floors. I was informed that in the new wards there was not to be screening above the wall plate under the eaves, or on the jack-roof. The experience in Panama is that screening is required especially under the eaves.

There is separate ward accommodation for dysentery. In the latrine the excreta are deposited in a dry cement trough, which at frequent intervals is washed down with a disinfectant (? Jeyes' fluid) into a large pit. The pit is emptied once a month.

The latrine was free from objectionable smell, and no flies were present. The dispensary was well furnished. The operating room was well provided with instruments; and there was a room for microscopic examination of blood, and other material from the wards.

The work of the medical officers is almost entirely confined to the hospital. Although visiting the estates from time to time to inspect the sanitary arrangements and to attend sick Europeans, it has been found most satisfactory to send sick coolies to properly equipped central hospitals rather than call the medical officers to see the coolies on the estates. Coolies are allowed to be one day off work, and are given simple treatment if they complain, but do not wish to go to hospital. If, however, not fit for work on the second day, they are sent to the hospital in a spring bullock-cart. Like most Sumatra hospitals, this is a combined hospital, and received patients from ten estates, the farthest of which is 18 miles away. Three of these estates have not contributed to the cost of building the hospital, and are called Outside Estates in Table 6.1, which shows the number of coolies in hospital on 5th March 1913.

All new coolies are passed through hospital, and subjected to thymol treatment for ankylostomiasis. The 445 coolies represent the sick from a labour force of 8596 on the

Table 6.2 Spleen rates of children on the Tandjong Kassau Estate

Coolie quarters	Number of children examined	Number with enlarged spleen
New lines	12	1
Old lines	41	1
Total	53	2

combined estates. In practice the estates provide 5 beds per 100 of the labour force, and this is usually found to be ample.

During 1912 there were 6025 admissions to the hospital from all causes, including the admissions of new coolies for thymol treatment. For malaria there were 611 admissions, or a rate of 71 per 1000 of the labour force; that is, 5 per 1000 less than the malaria rate in Panama in 1913, and 39 less than the rate in Panama in 1912. The death rate of the whole group of estates was 33.8 per 1000.

For Tandjong Kassau Estate alone in 1912, the malaria admission rate was 187, and the death rate 42 per 1000. This and other estate death rates in Sumatra refer, however, only to the indentured labourers. The children are treated usually by native doctors; and Mr Blick tells me the infantile mortality is high. The children are only sent to hospital if the mother wishes this; and their deaths are not taken into account in estimating the death rate of the labour force.

Of eighteen Europeans, the staff of the Tandjong Estates, only one has suffered from malaria in the past eighteen months. Tandjong Kassau Estate is undulating, and in the Federated Malay States would in 99 cases out of 100 be intensely malarious. Mr Blick's bungalow is situated at the junction of two ravines; yet he and his family and servants do not suffer at all from the disease, and all look in good health.

The children on the estate are equally free, as will be seen from Table 6.2; the overall spleen rate is 3.9 percent. The spleen of the single positive child in the new lines was just palpable, and I could get no history of the child having had fever. The positive child in the old lines had arrived only two months before from Java. Its mother said it had had fever before arrival. All the other children looked in excellent health. There can be no doubt this estate is free from malaria, except what is imported.

6.2.3 Mosquitoes. In the stables close to Mr Blick's house numerous *A. rossii* were captured, but no other species. In the ravine below there were a number of drains the water of which ran sluggishly. In some drains were leaves and algae; and the water had a rather slimy look. Many larvae were taken from the sides of these drains. Most of them died on the journey back to Medan; but a few ultimately hatched out as *A. rossii*. Similarly in a ravine near the new lines, larvae in abundance were found among the leaves at the side of the drain. The water here was also slimy, and rather dirty looking. The larvae were easily captured. Through a flat part of the estate to the hospital runs a stream, about 10 feet wide by 3 feet deep. At its sides I captured one pupa and several larvae. One of the latter had the white mark on its neck indicative of *A. kochii*; but

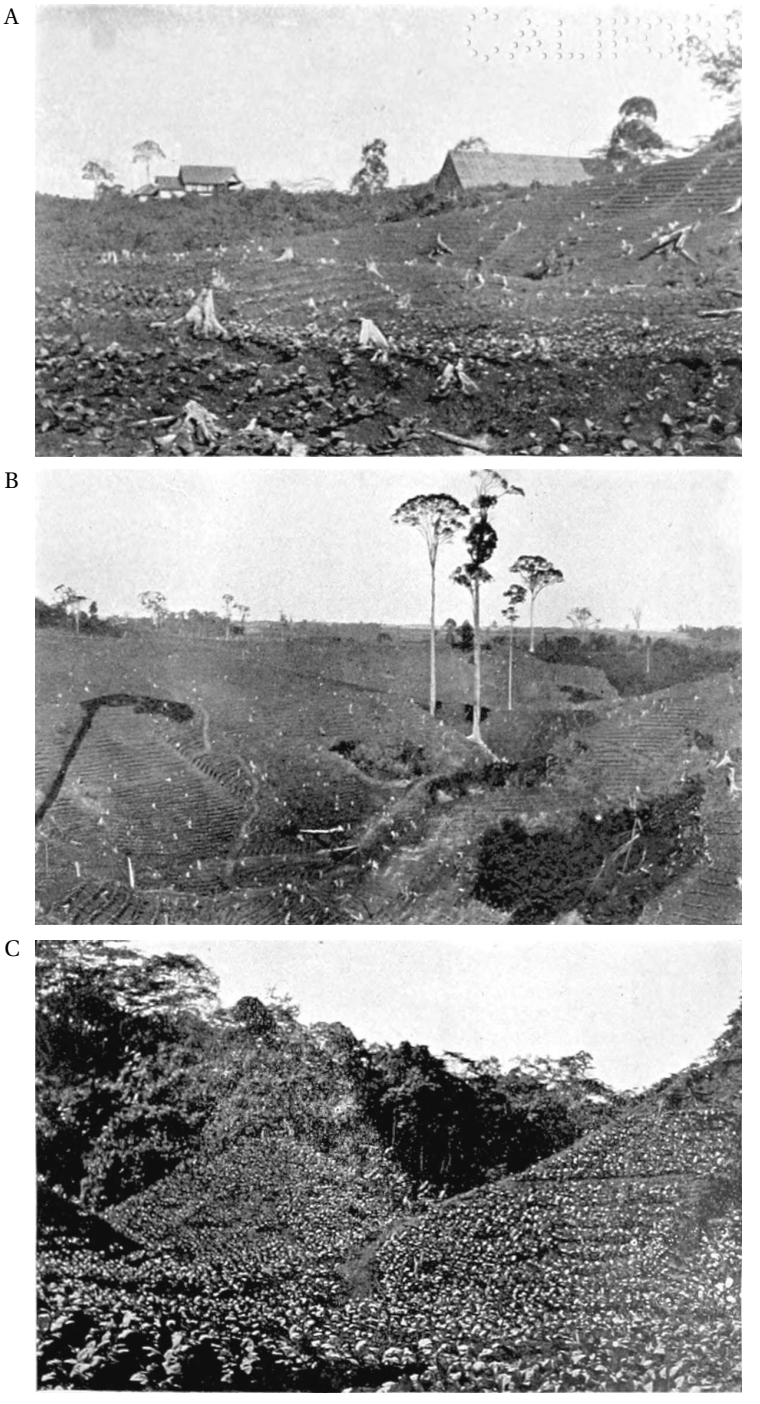


Figure 6.1 Toentoengan estate, Sumatra. A: Coolie lines on ridge. B: A ravine. C: Jungle at boundary of the estate, close to coolie lines.

unfortunately it failed to hatch out. I noted many small pieces of vegetable matter and debris in the stream.

My conclusions from this visit were—(a) that the estate was free from malaria contracted on the estate; (b) that this was due to the absence of *A. maculatus* from the ravines; (c) that this freedom from *A. maculatus* might be due (*a*) to the constitution of the water being unsuitable to it, or (*b*) to *A. maculatus* not occurring in Sumatra.

6.3 Toentoengan estate: a typical hill land estate, yet free from malaria

On March 6th, Mr van Tyn called sharp at 7 a.m. and drove me in his car inland to Toentoengan Estate, the highest estate belonging to the Deli Maatschappij. It is between 200 and 300 feet above the sea level. On arrival at the estate it was at once apparent that in every way it could be classed as a hill estate, and in Malay would be, except by the very rarest good fortune, intensely malarious.

From the road the path runs for about half a mile on the level, but surrounded on all sides by the curious bank-like hills seen in Sumatra. On the left was jungle, the boundary of the estate. In the flat portion of the estate was a small stream and a number of drains; in the stream no larvae were found; nor was my search in the drains more fruitful until I reached their upper ends. Here, especially in one drain, where there was grass, I took many *Culex* larvae, but no *Anopheles*. Climbing over a ridge, I reached a ravine which came out of the jungle only 100 yards away. The water in the drains was beautifully clear, quite unlike what had been seen in the lower portions of the country. I should mention the soil of this estate was black, not the usual red. In the masses of algae, *Culex* larvae and egg-rafts were abundant; but the most careful search did not discover a single *Anopheles*. In some of the drains there was considerable current.

Proceeding to the next ridge, I had a magnificent view of the block of the estate under cultivation, and of the country in general. But of most interest to me was a deep ravine, with many side branches and steep sides scored in the earth a full hundred feet. The sides were so steep that the path down consisted of steps. If anything was to be called a ravine this deserved the name, and it was with some haste I descended. But here, as in the previous ravine, no *Anopheles* could be found. Of *Culex* there was abundance, especially in the algae. And I noted particularly that these mosquitoes were present in the algae of the various streams, despite the existence of shoals of small fish. When I returned to the main road, my man reported he had not caught any adult *Anopheles* in the houses.

The labour force consisted last year of 1200 coolies, of whom 1000 were indentured. Of this force, nine died in hospital, and one on the estate, which gives a death rate of 8.3 per 1000. From a consideration of these figures, from my failure to obtain larvae in the streams and the adult insects in the lines, it is apparent the health of this labour force is infinitely better than it would be on a correspondingly hilly estate in the Federated Malay States, and the conclusion is suggested that this is due to the absence of malaria.

6.4 The labour system in Sumatra

The labour system in Sumatra is exactly the reverse of what it is in the Federated Malay States. In Sumatra practically nothing but indentured labour is employed. The composition of the labour force preferred by managers is half Chinese and half Javanese. The former being more industrious, set the standard of work. But to trust to free Chinese labour alone would be to court disaster. For the Chinese guilds, or trade unions, are well organized; and with the demand for labour being greater than the supply, they could easily afford to, easily could, and certainly would ruin an estate that refused their demands. The coolies receive their full wages in cash, and they feed themselves. But the estate provides a shop where rice is issued at a price fixed by the Controller of Labour.

The Javanese are recruited in Java; the Chinese locally. There is practically no absconding, since no coolie can obtain employment without establishing his identity; and, under the Dutch system, he is required to register in the district in which he resides, or in any new one to which he removes. One of the advantages of indentured labour is that the manager of an estate can count on having a definite labour force at the season specially suitable for planting out the tobacco plant, or for gathering in the leaf at the moment of maturity. With such a delicate plant, to miss a spell of dry or wet weather is to miss the season, and lose a year's crop. These times would be the Chinaman's opportunities for squeezing the estate. Under the circumstances one can understand why the Sumatra planter is a strong advocate of the indentured system. The labour is under the control of a government department; and, as will be seen, under it the coolies enjoy a degree of health and prosperity unapproached by anything they have ever enjoyed or ever are likely to enjoy elsewhere.

6.5 Deli Maatschappij hospital at Medan

This, the largest hospital belonging to the Deli Maatschappij, contains about 600 beds. Dr Römer, the chief medical officer, kindly showed me over it. Most of the buildings have been up many years; nevertheless, the wards are large and freely ventilated through the lattice-work sides. There are no verandahs; the floors are of cement; the roof of shingles. The beds are either plain planks or wire mattresses. The latter are disliked by the coolies, and are not used unless the other beds are occupied. There is an excellent dispensary, and an up-to-date operating room. An examination room, fitted with X-ray and other apparatus, enables the fullest possible examination to be made in obscure cases. The latrines consist of troughs full of disinfectant. These and all the sewage from the hospital drains are run off into the river once in the twenty-four hours.

In his office the medical officer has a fine medical library. Careful records are kept, and the Annual Report of about fifteen closely written pages deals with each disease in detail, and is full of statistical tables and charts. Dr Römer was kind enough to allow me to peruse his report and make extracts; and since my return to the Federated Malay States Dr De Jong has kindly given me some additional information. It is a most interesting record of the health of a great tropical labour force, whose diseases have been studied with scientific care (see Table 6.3); and it is a record of which any hospital might be proud.

Table 6.3 Annual case statistics of the Deli Maatschappij Hospital at Medan, 1900–1911

Year	Labour force	Admissions	Death reate of hospital (%)	Death rate per 1000 of labour force
1900–01	8,766	3,846	11.4	50
1901–02	8,832	3,320	7.4	27
1902–03	10,459	4,316	6.0	25
1903–04	9,940	4,812	4.4	21
1904–05	9,294	4,287	4.8	20
1905–06	9,796	4,525	2.4	11
1906–07	10,633	4,643	3.5	15
1907–08	11,009	5,734	3.0	16
1908–09	9,866	5,407	2.6	14
1909–10	9,916	4,291	1.9	9
1910–11	10,290	4,289	2.6	12

Table 6.4 Malaria admissions and deaths at Medan Hospital in 1910–1911

Malaria form	Admissions	Deaths
tertian	200	3
quartan	24	1
tropica	30	0
Total	254	4

6.5.1 Ankylostomiasis. New coolies are not admitted to the hospital for thymol treatment, as is done at Tandjong Kassau Hospital; and in 1910–11 only twenty-eight cases of ankylostomiasis were admitted, of which one died. In addition, 219 cases of anaemia were admitted, with one death. Even assuming that all the anaemia cases were due to the ankylostome, it is evident that the worm does little harm to the labour force. Whatever the truth may be as regards the Javanese coolie in Sumatra, I have never been able to accept the view that the Tamil coolie in the Federated Malay States was decimated, or even seriously handicapped, by this worm. My reason for thinking the importance of the worm in this country to have been exaggerated, is the fact that it is present uniformly in 90 percent of all our labour forces, whether healthy or unhealthy; and that the death rates vary with the spleen rates, while the worm is a constant.

There are reasons, however, quite apart from the worm, why the use of the latrines on estates should be extended; and I am glad to say that is actually taking place. The real difficulty, and not a small one, is to get the coolie to use them.

6.5.2 Malaria. No less significant are the figures for malaria. The numbers shown in Table 6.4 give an admission rate for malaria of only 24 per 1000. In 1911–12 the

Table 6.5 Causes of dysentery at Medan Hospital in 1910–1912

Cause of dysentry	1910–11	1911–12
Amoeba[1]	54	44
Bacillus Shiga[2]	17	14
Bacillus Strong[2]	5	0
Bacillus Flexner[2]	0	5
Bacillus Y[2]	7	19
No bacterial diagnosis	76	65
Total	159	147

[1] now named *Entamoeba histolytica*
[2] now classified as *Shigella* species

admissions for malaria amounted to only 220. The rate of twenty-four is just less than one-third of the admission rate for malaria in Panama for the year 1913. In Panama the result is attained, as we shall see, by organization and infinite care; in Sumatra an even greater freedom from malaria exists, simply because over large tracts of the country malaria is not endemic. What a different picture there would be in Medan Hospital were the disease endemic on the Deli Maatschappij Estates.

6.5.3 Dysentery. Working along with the Medical Institute, it has been possible to classify the dysentery cases according to their causes. The numbers listed in Table 6.5 do not represent a large amount of dysentery in so large a native labour force; but it takes a considerable toll in lives. Unfortunately there is nothing to indicate a prospect of dysentery disappearing, or being even materially reduced in amount, as is shown in Table 6.6.

Most sanitarians nowadays agree with Colonel W. J. Buchanan[1] that the water-borne theory of dysentery and typhoid has long broken down, and cannot account for the persistence of a few cases of dysentery or typhoid. When these diseases are conveyed by water, the outburst is sudden, severe, and widespread, and is quickly stopped on changing the water. Such outbreaks one sees when an army is in the field. But to think of dysentery purely as a water-borne infection is to miss the fact that there are often other causes really responsible for the outbreak, and that the removal of these causes will remove the outbreak.

6.5.4 Principal Diseases. Table 6.7 shows some of the principal diseases that affected the labour force in 1910–11. It will be noted that dangerous infectious diseases like cholera, typhoid, smallpox, and cerebrospinal meningitis appeared, and their presence easily accounts for the rise of the death rate from 9 per 1000 in 1909–10 to 12 per 1000 in 1910–11. That the death rate only reached 12 in the presence of these diseases seems to me to indicate how rapidly the medical staff got them under control.

[1] "The Prevention and Treatment of Dysentery in Jails," by Lieutenant-Colonel W. J. Buchanan, I.M.S., Inspector-General of Prisons in Bengal, *Trans. Bombay Medical Congress*, 1909.

Table 6.6 Admissions and deaths due to dysentery at Medan Hospital

Year	Cases	Deaths
1900–01	163	103
1901–02	119	59
1902–03	139	82
1903–04	115	61
1904–05	74	44
1905–06	50	25
1906–07	86	37
1907–08	117	95
1908–09	133	55
1909–10	112	21
1910–11	159	58
1911–12	147	30

Table 6.7 Principal diseases at Medan Hospital in 1910–1911

Diseases	Admissions	Deaths
Malaria	250	3
Dysentery	159	58
Bowel diseases	306	86
Cholera	48	18
Typhoid	20	5
Smallpox	40	11
Cerebrospinal meningitis	43	41
Ankylostomiasis	57	2
Anaemia	155	1
Pulmonary tuberculosis	36	14
Beri-beri	66	7
Pneumonia, croupous	142	40
Pneumonia, catarrhal	142	
Broncho-pneumonia	133	5
Venereal diseases	268	3
Nephritis (acute and chronic)	20	9
Surgical diseases	689	11

Figure 6.2 A ravine in Bandar Talu Estate, Sumatra

6.6 The Medical Institute

This fine institute belongs to, and is supported by, the estates in N.E. Sumatra. It is much superior to what the London School of Tropical Medicine was before the recent extensions. The institute carries out all complicated diagnostic work for the estates. It also makes immunizing serum for human and cattle diseases, and generally is of assistance to the estates in all affairs where exact scientific observation and work are required. Not only does it justify its existence by this routine work alone, but Dr Kuenen has found time to carry out original research. Dr Vorvoart will shortly join him as assistant director. At the time of my visit Mr Swellengrebel, protozoologist of the Amsterdam School of Tropical Medicine, who had been studying plague in Java on behalf of his school, was working in the laboratory. To Dr Kuenen and these other gentlemen I was indebted for much assistance, as will be seen from the following narrative, and not less for placing a room in his laboratory at my disposal.

While examining an *A. rossii* that afternoon I noticed a "tick" or "mite" on it. It was not red like those that I had seen on *A. umbrosus*, and that had been described by Dr Strickland, but pale straw coloured. It was seen by Dr Kuenen and Mr Swellengrebel, but unfortunately it dropped on to the desk when we moved it, and we could not find it again. What it was could not be ascertained.

6.7 Bekioen and Bandar Talu: hill land estates

6.7.1 Bekioen. March 7th. At 6 a.m. Dr Kuenen and Mr Swellengrebel called, and we started for Bekioen, where an outbreak of malaria had occurred last year. The road lay roughly in a north-west direction until we reached the town of Banjai on the Sungei

Bingai. The town is clean, and the river bed lies some 20 feet below. Then the road struck more inland towards the main range. On this road again it was many miles before we saw jungle, but shortly before reaching our first stop we ran through a new clearing some 10 chains wide on each side of the road. This was part of Bekioen Estate. I was informed later on that no malaria existed, nor had existed, among the labour force on this clearing. Such would not have been the case in the Federated Malay States. At 7 a.m. we turned off the road into one of the clumps of casuarina trees of which I have spoken, and drew up at Dr Hauzinga's house, one of several occupied by the European staff of the estate. Each house has its garden of 2 or 3 acres. Dotted about, in no apparent order, and quite close to each other, they are nevertheless isolated by trees and hedges, while all together they form a delightful oasis in the wilderness of tobacco fields and temporarily abandoned land. Substantially built, furnished much more in European than Eastern fashion, and surrounded by beautiful gardens, these houses suggest a home more than anything to be seen in the Federated Malay States.

One of the great causes which invalids both men and women from the tropics, is what is called neurasthenia. It may be defined as a condition of the nervous system supersensitive to the impressions it receives; when, in fact, everything is a worry. It comes from overwork, want of rest, and often follows other illnesses. Common in temperate climates, it is even commoner in the tropics; and I cannot help feeling that were the English to make their houses and quarters in the tropics as homelike as the Dutch do, there would be less neurasthenia.

6.7.2 Bandar Talu. After breakfast Dr Hauzinga took us to Mr Prins' estate, which is called "Bandar Talu." It is under rubber about two years old. The estate is much cut up by ravines, which are now being cleared of "blukar," i.e. small jungle. The manager's house and three sets of coolie lines are situated close to ravines. Although being cleared up, the water in the ravines had not yet been fully exposed, and we searched only in the more open places in two streams. Both streams were running very sluggishly. In the grass at the sides of the first stream many small larvae were taken. In the second many large black larvae were found. They suggested *A. sinensis* or *A. barbirostris*. Unfortunately they died; the long motor-car journey drowned them.

Dr Hauzinga said there had been as many as seven cases of malaria in one month last year from the estate, i.e. less than 5 percent per month of the labour force. The total number of deaths in the year was, however, only two. Both deaths were from dysentery. The water-supply on the estate was considered bad. Table 6.8 shows that the labour force almost trebled in the year. On an examination of the children (the number examined unrecorded, but could not have been many), I found none with spleen enlarged.

Mr Le Prins says there are many "Agas" (*Ceratopogon*)—miscalled "sandflies" in Malaya). My man was unable to catch any *Anopheles*.

6.7.3 Sumatra's profile. Bandar Talu Estate is 600 feet above sea level, and from one point a magnificent view of the country is obtained. I might call it a profile view. At first slowly, and then more quickly, the line gradually rises from sea level until it ends almost

Table 6.8 Workforce on Bandar Talu Estate, 1912

	Number of coolies	Deaths
January	63	-
February	79	-
March	130	-
April	131	-
May	147	-
June	150	1
July	174	1
August	173	-
September	172	-
October	173	-
November	173	-
December	173	-

vertically in a smoking crater nearly 5000 feet up. The air was extraordinarily clear that day, and every detail of a gorge below us was visible.

The gorges of Sumatra form a very striking feature of the scenery. The land, except when we have actually reached the main range at an elevation of nearly 2000 feet, appears to the eye to be level as we travel along the roads. Then suddenly, almost without a warning, a chasm opens, in the bottom of which a river is dashing down among great and small boulders. These chasms are river valleys; but the edges of the valleys are not worn away, as one would expect in a country with so heavy a rainfall as North-east Sumatra. The edge is more like the edge of a canyon, which cuts through the tableland or "mesa" of the arid regions of America, than anything I have seen. Yet in this part of Sumatra the land consists simply of volcanic ash, not much compressed, with a good sprinkling of volcanic boulders. The explanation of the sharp edges is perhaps to be found in the gluey nature of the soil, formed from this ash when wet. Friable enough when dry, it sticks like glue when wet. In Hawaii, which is similarly volcanic and with a similar soil, I found walking on the wet red earth very difficult and fatiguing. Every few minutes it was necessary to stop to knock off the masses of earth which adhered to my boots. As we shall see later, this same soil is found in Panama, and its peculiar character has led to very important modifications in their anti-malarial methods.[1]

6.7.4 Kuala Namoe Estate—formerly malarious. Returning from Bekioen in time for tiffin in Medan, I set off immediately afterwards for Kuala Namoe, about 14 miles out, accompanied by Dr Vorvoart. Two years ago Dr Vorvoart was medical officer to this estate, and at that time there was a considerable amount of malaria. On the way, we picked up Dr Schüffner, whose name is familiar to every student of tropical medicine as the discoverer of the stippling of the blood corpuscle infected by certain forms of

[1] see Chapter 11.

the malarial parasite. Dr Schüffner took us to a number of pools in borrow-pits, but we found no *Anopheles*. The water in the pools was dirty, and had any mosquitoes been obtained I have little doubt they would have been *A. rossii*. Kuala Namoe Estate may be called flat, and is so as far as the eye can see. About 25 to 30 chains from the lines there is a swamp, caused by the overflow, in wet weather, of a small stream. At the time of my visit the swamp was dry, and the stream was confined to its narrow and rather ill-defined channel. The edges were covered with a heavy growth of grass, and the current in the centre ran about three miles an hour. It struck me at once as an ideal breeding place for *A. albirostris*. Many larvae were taken, but at the time I left Sumatra they had not hatched out. In the lines, however, my man caught four *Anopheles*, namely: (a) *A. rossii*, (b) *A. sinensis*, (c) *A. albirostris*. I have no doubt the *A. albirostris* came from this stream. The estate is now healthy, and an assistant's bungalow at one time full of malaria is now free from it.

6.8 Tandjong Morawa and Rantan Pandjang

6.8.1 Tandjong Morawa. March 8th. Leaving at 6.30 a.m., I motored out to Tandjong Morawa, where Dr Schüffner is medical officer. His house, like the others of the company, is in a beautiful garden on the banks of a considerable river. The hospital, which is close to the house, receives patients from several estates. In his laboratory there is a large room well equipped both with apparatus and books. Dr Schüffner showed me microphotographs of the various *Anopheles* that he had captured and sent to Dönitz for identification ten or twelve years ago. Dönitz had identified them as *A. kochii*, *A. plumigar* (? *sinensis*), and *A. rossii*. Dr Schüffner had not done much recent work on mosquitoes, as malaria was not a problem for the estates under his care. He, however, had paid some attention to Rantan Pandjang, where malaria exists, and after seeing the hospital we drove there.

The hospital at Senembah is in nicely laid out grounds. The floors are of cement. All serious cases are treated in mosquito-proof portions of the wards, so that the patients may not be annoyed by the insects. All dysentery cases are treated in a mosquito-proof ward, which, if necessary, is emptied and used for cholera cases. The screening throughout was in good order. The water for the hospital is from a well in the grounds from which it is pumped to a tower.

Dr Schüffner submits all the new coolies to a course of thymol, and I saw the method carried out here on a considerable scale. After the treatment, each patient brings the large enamel vessel with his excreta down to the river, and that morning there were some thirty patients. The vessel is filled with water from the river, and then decanted. This is repeated until all the faeces are washed away, while all worms are left behind. The whole process is carried out quickly by a Chinese coolie. The worms are then examined under the microscope, and classified. The two forms of ankylostome, *Ankylostoma duodenale* and *Necator americanus*, male and female, and the various other worms, *Ascaris lumbricoides*, *Trichocephalus dispar*, etc., are separated and their numbers are recorded on the patient's chart. I may add, the river is 15 to 20 feet below the level of the surrounding land.

6.8.2 Rantan Pandjang. We then motored to Rantan Pandjang, an estate about 10 miles from Tandjong Morawa where Dr Schüffner had found much malaria among the natives. For the first part of the road we were on land similar to that with which I was now familiar, namely, red, light yellow, or white soil, with the groundwater 15 to 20 feet below the surface. Then we came to a part which was, from its vegetation, evidently a swamp in wet weather. At that time it was dry, but the groundwater stood only a foot below the surface. No big jungle could be seen, the land being covered by secondary jungle about 30 feet high. A creek along which the road was was tidal, but the water was fresh. In a pool we got several large black larvae, which had frontal tufts like *A. sinensis* or *A. barbirostris*.

Continuing for another mile or so, we came to Rantan Pandjang, a considerable village. Dr Schüffner was evidently well known in it, and a welcome visitor. A number of children were at once brought for examination, but he observed one could not be sure the sick were brought, and such an examination was liable to give unduly favourable results.

6.8.3 Method of obtaining children for spleen examination. To overcome this difficulty, I suggested we should make a house-to-house visit to a portion of the village, with children as guides, to those houses in which there were children. I have found this a very effective way of obtaining both information about children, and the children themselves for examination. After talking to some of the older children in a village, they will generally submit to examination, and once they have been examined they usually show great zeal in bringing others for examination. In a very short time a number of children can be attracted, and the examiner has then overcome all his difficulties. In going from house to house, the guides tell you beforehand whether it contains a child or not. Mothers, under these circumstances, rarely deny the existence of a child, and the child rarely resists being brought to the examiner by its own companions. In a few minutes, too, these invaluable small assistants learn to loosen any clothing round the child's waist that might interfere with the examination, and in a country with many different races they act as able interpreters.

By such means the work can be done with a maximum of speed and minimum of resistance. I would go further, and say that it serves as the best possible introduction a European medical officer can have to a native race, and completely eliminates all chance of error through the examiner seeing only the healthy children. The keenness of the children, their delight in the new game, their intelligent questions, and their desire for information, have made these days for me among the most interesting in my life in the East, and always a delight. It is a great game for all of us. Among adults "slackness" is common; among children it is never seen, unless perhaps when the poor mites are actually suffering from "fever," and even then it is not invariably present.

In this way we went from house to house until we had examined thirty children. Of these, ten (or 33 percent) had enlarged spleen. One spleen alone was much enlarged, and it was found in the only child that looked ill. We then searched for larvae, but were not only unsuccessful in finding *Anopheles*, but almost equally so in finding possible breeding places. The weather had been very dry for some time, and the ground was

baked hard. Even an extensive rice field was quite dry in holes a foot deep. Ditches 3 to 32 feet deep were also dry, and the water found was only in a few wells about 5 feet deep. In these *Culex* larvae existed. My man was unable to catch any adult Anophelines. It would be very interesting to visit this place in the wet season, for the spleen rate denoted a considerable prevalence of malaria.

Crossing a branch of the main creek on a doubtful looking bridge, we walked about a mile to a fishing village on the sea, called Bagan Serdang. The houses are built on the ridge of sand which forms the beach. On the sea side the sand runs off into the long mud shore so common in these parts. And on the inland side the land is a mud swamp, drained by tidal creeks.

Of eleven children two had enlarged spleen (18 percent). We could find no *Anopheles* breeding places.

6.8.4 Summary of findings. Thus in Rantan Pandjang and Bagan Serdang there was clear evidence of endemic malaria, in confirmation of Dr Schüffner's statement. And with the history of Balawan, before alluded to, there can be little doubt this low-lying part of the coast is malarious, just as it is in the Malay Peninsula. On the most interesting question of all, what the carrier of malaria is, I can throw no light. Undoubtedly Rantan Pandjang is a very favourable place to study it. It is of no small practical importance to determine whether or not *A. ludlowi*, which breeds in brackish water, is a carrier of malaria.

Major Christophers has found zygotes in the stomach of this mosquito in the Andaman Islands, where malaria appears to be found only along" the sea coast and salt-water inlets. Dr De Vogel of Java has also recorded the presence of mosquitoes in the brackish water of sun-cracked mud on the sea coast associated with severe malaria. The mosquitoes were identified by Theobald as *A. rossii*, but as this was as long ago as 1908, it may be the mosquito was really *A. ludlowi*.

My feeling, from what I have seen in the Federated Malay States, is that *A. ludlowi* can exist without producing malaria, and indeed that malaria will disappear from a place when steps are taken which abolish only *A. umbrosus*—a proved carrier—yet leave very large numbers of *A. ludlowi*. The question is one of great importance, and further investigation is required.

6.9 The Sumatra highlands

March 9th. An early start was necessary, and at 4.45 a.m. I was called for a cup of coffee, which would make the run in the cold morning air more tolerable. In due course Dr Kuenen, Dr Vorvoart, and Mr Swellengrebel arrived in the car, and we got away with the first glimmer of daylight. It was a splendid road on which we travelled, and had been constructed for military reasons connected with the long-drawn-out Acheen rebellion.

A few miles out from Medan we crossed something that at first glance looked like a railway cutting, about 20 feet deep, only instead of rails there was a masonry or cement channel about 4 feet wide, with small transverse bridges supporting every 20 feet. This is the water supply for Medan, the source of which we were to see farther up the hills. For the first few miles we were in wide, open country, and had a magnificent view of

the mountains. The road was rather tortuous, and we kept on the tops of the "mesas." Although apparently flat, the engine was having collar work all the time, but its 40 horsepower took no notice of the 1 or 2 percent grades.

Suddenly the road began to descend into a valley. The turns were very sharp, and required careful driving; but our driver was an expert. In this valley there is the highest tobacco estate in Sumatra. The road then creeps up a small valley, and crossing a watershed plunges into the gorge of the Sibolangit River. Crossing the river by a bridge, I noticed men collecting stones from the river bed, which are the only quarries they have in North-east Sumatra. All the roads are covered with water-worn pebbles. Near to the sea it is more difficult to get stones, and so many of the roads are unmetalled. From the road we now had a magnificent view of the gorge, and again I was struck by the sharp edge.

Looking back to my visit to the American chasm, and knowing the magnitude of that great work of nature, it may appear absurd to compare this Sumatra gorge with the Grand Canyon, yet to the eye the comparison is by no means absurd. The Grand Canyon is on so great a scale, and the atmosphere is so clear, that the eye fails to realise to the full the 13 miles across, and the 3000 feet drop to the top of the inner gorge, or 5500 feet to the bottom. The Grand Canyon produces its effect, apart from its exquisite colouring, as much through the mental consciousness that it is a mile deep, as through any actual visual realization of the fact. Here in Sumatra the gorge is nearly 1000 feet deep, a depth quite sufficient to impress the eye. Its steep sides clothed with trees were something very different from the canyon in the West; yet having seen the two, I would venture to say that this gorge is one of the most beautiful sights in the world, and a visit to it, something to be treasured in memory.

The road now takes a sharp bend, and above us was the Sibolangit plateau. From its base come the springs that supply Medan with water. Where the water enters is unknown. Probably it has had a very long underground passage, for when it comes out it is free from all organisms. Evidently it has come through cleansing fires in its subterranean course. The climb of 800 feet up to the plateau above was stiff; but the road was in excellent order, and continued its way up on a steady, if severe, grade.

Once on the top, we were in the country of the Bataks, a people in many ways different from the Malays, and slow to come into contact with the white man. At 1800 feet we passed the house of a missionary, who has long been established among these people, and whose existence was at one time more than a little precarious. From time to time we passed curious-looking objects, resembling gigantic beehives. I made the very bad guess that they were huts, but was told they were stacks of rice straw.

The road was winding about now rather uneasily, for the general gradient of the land had risen to about 5 percent. We soon reached 850 metres (2800 feet). The road now runs in almost a straight line to the Sanatorium, situated at a level of 3000 feet above the sea, and backed by the main mass of the mountains. From this point the road begins a long zigzag up the mountain side, with a sheer rise of 1200 feet in what would probably be only a mile on flat land. As it twists and turns on itself, it strongly reminds one of the climb to Lake Chuzenji in Japan. At 8.30 a.m. we stopped at the top of the

hill for breakfast, for which we were all ready. No less did we enjoy the view, which was truly magnificent; for we could see away to Medan, and all the surrounding country, although not the sea beyond Medan, because of a slight haze.

The next portion of the road was no less grand than what we had come over; crossing a watershed, we looked down on the land south of Medan. Suddenly, after a few more turns, we left the Pass, and almost in a twinkling the huge jungle gives place to the wide, open Highlands of Sumatra. The change is extraordinarily sudden. The great jungle trees are, I suppose, the product of hot mist and currents rising up the valleys. At the summit these currents continue upwards, and the vegetation on the plateau gets no benefit from them. Whatever the explanation, the change is very sudden. In one moment we are in the most magnificent tropical jungle; in the next, in open plain covered with grass or small scrub. Far away in front is the great inland lake, Toba-mere, and at least 50 miles away in the same direction we see three extinct, but almost perfect, volcanic cones.

Three or four miles from the Pass are the bungalows belonging to the Deli Maatschappij and other companies, who realise the importance of giving their employees a change to the cool as frequently as possible. The bungalows are substantially built, and command magnificent views of the lake in front, and of Sampoelanangin, the smoking volcano, behind.

Here our party broke up. Drs Kuenen and Vorvoart went off to take samples of water from a proposed supply which was to bring water from the hills to the bungalows by gravitation.

6.9.1 Brastagi. Mr Swellengrebel and I went to the Batak village of Brastagi. The village consisted of a number of houses like Noah's arks on stilts, in each of which live a number of families in separate cubicles. In the centre of the village was a building, to which I was told all youths were banished from the parental abode when they had reached the age of indiscretion.

In other respects the social conditions were as different to those in the Federated Malay States as could be imagined, and many curious things were seen. Very heavy earrings are worn by the married women. They consist of coils of silver so heavy that they must be supported by a cloth over the head. Were the support to give way, the ear would be torn. Old-fashioned ladies wore these continuously throughout their lives, for the silver was coiled in situ and could not be removed; up-to-date matrons have had a screw-joint put in the middle of the ornament so that it can be removed. I wonder if the old dames can see in this simple consideration for comfort a sign of loss of self-respect and modesty in the rising generation?

In the village we examined twenty children without finding an abnormal spleen. Only one little girl looked ill. On inquiry we found she had suffered from dysentery for a fortnight, so we arranged for her to get medicine at the bungalow, which she did. The village is on the edge of a gorge, into which we descended by an almost vertical path, consisting of steps cut in a little funnel in the side of the cliff. At the bottom a large stream of water gushed from the rock, and was then made to irrigate rice fields in the valley. These were admirably constructed in the usual descending series. Both

Figure 6.3 Rice fields at Brastagi, in the Bakak Highlands of Sumatra

in the rice fields and in the grassy channels we found *Anopheles* larvae in abundance, but unfortunately all the large ones died on the journey down, and the species was not determined.

Late in the afternoon, on our way back to Medan, we ran into heavy rain at the Pass. Great clouds of vapour were rising from the valley below, and it was now easy to understand the magnificent jungle even at this height. The rain cleared off while we were actually descending the steepest part of the mountain; but from the Sanatorium to the plateau it lashed as only a tropical storm can lash. The rainfall at the plateau is said to be 6 metres (about 240 inches) per annum. I believe it, after what I saw.

6.10 List of the *Anopheles* of North-east Sumatra

March 10th. The forenoon was spent in the laboratory with Dr Schüffner and Mr Swellengrebel in examining the larvae that I had collected. Unfortunately, almost all the pupae and the largest larvae had been killed by the long motor journeys, and the identification of the small ones was not always possible. However, the points of most importance in the specimens that we had gone over, and the confusion of the nomenclature of species, were cleared up as far as possible.

Many months later I heard from Mr Swellengrebel of the result of further investigation of the *Anopheles* of North-east Sumatra. He wrote that neither he nor Dr Schüffner could find *A. maculatus*, although they had "tried hard to find it. In Sibolga (N.W. Sumatra), where malaria tropica is prevalent, Dr De Vogel and myself only found *A. sinensis*, *A. ludlowi*, and *A. rossii*. Probably *A. ludlowi* is the carrier here."[1] The *Anopheles* that they did find are listed in Table 6.9.

[1] *A. maculatus* has since been found by Dr Schüffner in the Batak Highlands.

Table 6.9 *Anopheles* species in North-east Sumatra, as identified by Dr Schüffner and Mr Swellengrebel

A. rossii	*A. ludlowi*	*A. albirostris*
A. tesselatus	*A. leucosphyrus*	*A. kochii*
A. sinensis	*A. barbirostris*	*A. albotaeniatus*

6.11 Conclusions

As I said in the beginning of these notes, it was not to be supposed I could make original observations on malaria in the short time spent in the various countries visited in my journey. My object was the simpler one of hearing from the medical men on the spot, their views on malaria; of seeing to what extent their experience coincided with my own, and where it differed, in trying to account for the difference.

So it may be convenient here if I summarise my impressions—for I can call them nothing more—of the portion of Sumatra that I have visited:

1. That on the sea coast, as in Malay, malaria exists.
2. That farther inland, malaria is to be found in swamps on the sides of rivers.
3. That very rarely malaria may exist in elevations up to 1000 feet; but
4. That for all practical purposes the hill land corresponding to our hill land in Malaya is non-malarious.
5. That an admirable system of hospitals exists.
6. That whether or not indentured labour may be undesirable ultimately, at present it is giving the estates in Sumatra a much better start than they have in the Federated Malay States; and finally,
7. That with equality in land and climate, and labour extraordinarily free from malaria, Sumatra will ultimately become one of the finest tropical agricultural countries in the world.

7. Hong Kong and Philippine Islands

7.1 Hong Kong

Early in 1911 I had an opportunity of examining the *Anopheles* of Hong Kong. They had been identified first I think by Major James, when on the way with his regiment to the Boxer Rising; and this was confirmed afterwards by Mr Theobald. Three species of *Anopheles* have been found, namely, *A. rossii*, *A. sinensis*, and *A. maculatus*.

In the laboratory I found two specimens labelled *A. maculatus*; these I recognised at once as identical with our *A. willmori*, Leicester. For the reasons given before, I could not then accept the name *maculatus*; but *maculatus* is the true name. In Hong Kong, just as in other countries where this mosquito exists, malaria is intense, especially when many newcomers or non-immunes are concentrated. The popular explanation of this is that the outbreak is due to disturbance of the soil; and Hong Kong's medical history as regards this is indeed notorious. The mosquito breeds in the steep hillside streams. Great improvements in health have been effected by "training the nullahs," that is, by building smooth channels with granite blocks. The mosquitoes are not found to breed in channels which have a grade of from 20 percent to 50 percent, except in dry weather, when leaves accumulate and offer the larvae a hold. This danger is obviated by sweeping out the leaves in dry weather.

7.2 *Anopheles* and malaria in Formosa

A day's sail from Hong Kong is the island of Formosa. It lies between the 21st and 26th degrees of north latitude. Malaria has been reported from it, and in Ross' *Prevention of Malaria*, Dr T. Takaki, chief of the Sanitary Bureau of the Government of Formosa, gives the following list of *Anopheles*:

(1) *A. sinensis*, Weid;

(2) *A. listoni*, Liston;

(3) *A. rossii*, Giles;

(4) *Anopheles* species (from Taito);

(5) *A. annulipes*, Walk;

(6) *A. maculatus*, Theobald;

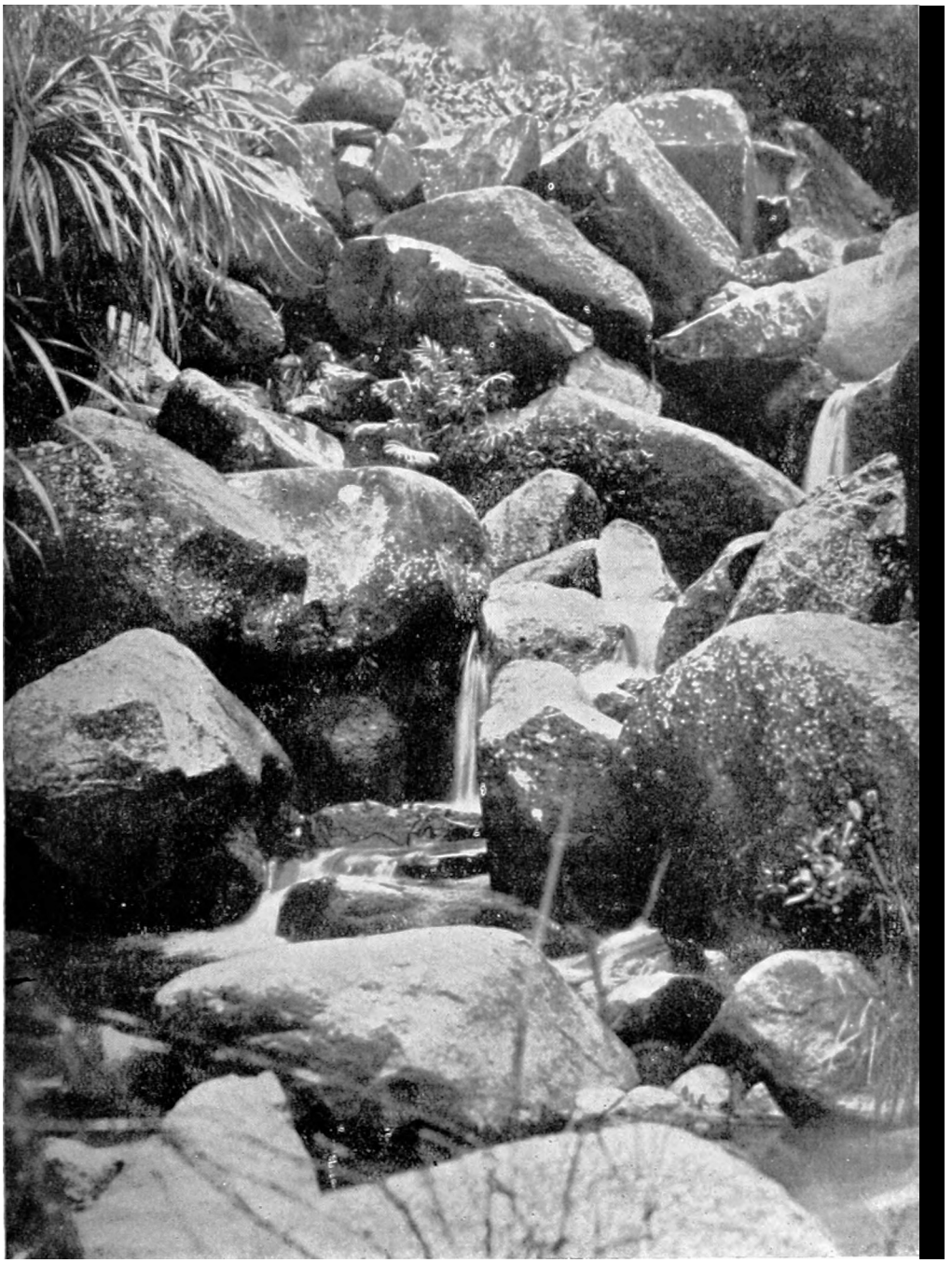


Figure 7.1 Natural nullah, or mountain stream, Hong Kong. The breeding place of *Anopheles maculatus*.

Table 7.1 Malaria cases and deaths among Japanese residents in the Formosan village of Kosenpo. Percentages of cases and deaths are relative to the population.

Year	Quinine	Population	Cases	%	Deaths	%
1906	−	785.2	4,209	546	59	75.1
1908	+	1719.2	1,467	82	9	5.2

(7) *A. fuliginosus*, Giles; and

(8) *A. kochii*, Dönitz.

He regards *A. sinensis* as carrying only benign tertian fever. It is the most prevalent mosquito. "Next comes *A. listoni*, a much smaller but extremely dangerous species." In another place[1] Kinoshita says of it:

> Every epidemic of Malaria tropica depends on the increase and decrease of *Anopheles listoni* … This mosquito develops very abundantly between the months of April and October. The new infections of tropical malaria begin also about the end of April and reach the highest number between June and July. *A. listoni* is generally more abundant in mountain regions than on the coast, and the distribution of tropical malaria corresponds. Taihoku, where *A. listoni* does not occur, is, therefore, free from tropical malaria.

Takaki says that *A. annulipes*, *A. maculatus*, and *A. fuliginosus* "are met with in the mountainous district." Further on he gives the record from Kosenpo, a village "lying in the southern mountainous district. … In April 1907, malaria prevailed terribly in this locality, especially among Japanese newcomers, so that 30 percent of the Japanese residents proved to be malaria patients." The figures for 1906 which he gives have a strong similarity to what we have in the Federated Malay States. The result of quinine administered, according to Koch's recommendation, was a marked improvement in health, but again, as in the Federated Malay States, by no means an eradication of the disease. And yet Takaki says, "the prophylaxis was strictly conducted under the care of police officials." Table 7.1 gives a summary of his statistics.

It should be added that although the total population is larger in 1908, the proportion of newcomers was greater in 1906 than in 1908. The figures for 1908 show a most satisfactory improvement in health; but even then eight men out of every ten became infected in the short malarial season which exists in Formosa.

It may be that *A. listoni* is solely responsible for all this malaria, and that *A. maculatus* is harmless in Formosa. But since malaria, as severe as that in Formosa, is found wherever *maculatus* alone exists, it would be safer not to overlook the possibility of *maculatus* being at least as important, if not more important, than *listoni*. It would also be interesting to have the Formosa *listoni* re-examined; like that named *funesta* in the Philippines, it may be *christophersi*, for the difference between these mosquitoes seems to be slight.

[1] Knab in *Proc. American Congress of Phys. and Surg.*, Washington, D.C., 1913

7.3 *Anopheles* species of the Philippine Islands

Nothing like the Indian malarial surveys have, so far as I am aware, been made in the Philippine Islands. Indeed, but for the work of Dr C. S. Ludlow, we would have little information about the mosquitoes of the Islands. Dr Ludlow, however, voluntarily received and classified all mosquitoes sent to her from the various islands, and from time to time has published her observations. In 1908, as her thesis for the degree of Doctor of Philosophy at the George Washington University, she wrote, and subsequently published, *The Mosquitoes of the Philippine Islands—the Distribution of certain Species, and their Occurrence, in relation to the Incidence to certain Diseases*; and in 1913 the War Department of the United States of America published an account of the *Disease-bearing Mosquitoes of North and Central America, the West Indies, and the Philippine Islands*, also by Dr Ludlow. Working as far back as 1901, when the little that had been published about mosquitoes was scattered about in the journals of different countries, and was often faulty and misleading, Dr Ludlow, like almost every other worker in new ground, described as new some species that had already been taken and described in other countries. But despite this her collection was a very valuable one, and her identifications were in all cases confirmed by Mr Theobald at the time.

In view, however, of the importance of this subject, I visited Dr Ludlow at Washington, D.C. She was good enough not only to allow me to examine her specimens, but she also gave me a collection which I handed over to the British Museum for renewed comparison with the type specimens. Mr Edwards has examined them, and in Table 7.2 I give what may be regarded as the most recent list of the Philippine mosquitoes.

With only two exceptions, the European, African, Asiatic, and New World species of *Anopheles* are distinct. The two exceptions were *M. funesta* (*A. christophersi*), which was reported from Africa and the Philippines, and *A. umbrosus*, reported from Africa and Malaya.

M. funesta is probably the most important malaria-carrying mosquito in West, Central, and East Africa, and great importance must have been attached to it, if it had been proved to exist in the Philippines. Dr Ludlow's identification was confirmed at the time by Mr Theobald of the British Museum; but the re-examination of a specimen by Mr Edwards leads him to the conclusion that the mosquito is *A. christophersi*. The other exception is *A. umbrosus*, which was reported from Africa as *A. strachanii*. It is possible that these two are identical, but as the museum collection of the Malayan species is rather poor, further material is necessary before a final decision is arrived at.

Dr Ludlow says: "*M. funesta* appears constantly in malarial outbreaks, so constantly, in fact, that the appearance of one specimen in a collection is enough to lead to a suspicion that malaria is present, and even a small number of them is usually accompanied or immediately followed by new cases, the number depending on the prophylactic control of the station." It was sent in, however, from only ten out of forty-two stations. From one station there is a report: "Parasites found in the blood of every man in the command."

It seems impossible that *A. maculatus*, a mosquito not more difficult to detect than *A. listoni*, can exist, when we consider the great mass of material which passed through

Table 7.2 *Anopheles* species of the Philippines

Name	Synonyms
A. formosus, n.s., Ludl.	
A. rossii	*Myzomyia rossii*
A. ludlowi	*Myzomyia ludlowi*, n.s., Ludl.
A. indefinita	*Myzomyia indefinita*, n.s., Ludl.
A. christophersi	*M. funesta*, Ludl.
A. tesselatus	*Myzomyia thorntoni*, Ludl.; *A. deceptor*, Don.
A. flavirostris, n.s., Ludl.	*A. punctuatus*, Theo. (closely resembles *albirostris*.—M.W.)
A. parangensis, n.s., Ludl.	
A. pallidus	*Stethomyia pallida*, Ludl.
A. sinensis	*Myzorhynchus sinensis*; *M. vanus*
A. barbirostris	*Myzorhynchus barbirostris*
A. pseudobarbirostris	*Myzorhynchus pseudobarbirostris*, n.s., Ludl.
A. fuliginosus	*Nyssorhynchus fuliginosus*; *N. nivipes*, Theo.
A. philippinensis	*Nyssorhynchus philippinensis*, Ludl.
A. kochii	*Christophersia kochii*, Chris. Halli. James; *Cellia kochii*, Theo.; *Nyssorhynchus flavus*, Ludl.

Dr Ludlow's hands. It is possible, therefore, that the Philippines furnish an example of malaria as carried by *A. listoni* unaccompanied by *A. maculatus*,[1] and although I have no positive information on this point, presumably *A. listoni* breeds in a stream in the Philippines, as it does in India. The elucidation of this matter will be of first importance in the prevention of malaria in the Islands.

Dr Ludlow also points out the association of *M. (A.) ludlowi* with malaria. "At the camp on the Banquet road no other *Anopheles* were taken ... During the period covered by the prevalence of this insect, malaria was extremely prevalent, and practically the only disease present; while later, when this mosquito disappeared and the collections were mainly Culicines, the fever also had largely disappeared." *M. ludlowi* was the only *Anopheles* from six other stations which showed prevalence of malaria. It is of great importance to determine if this mosquito does really carry malaria; the finding of zygotes in the stomach of specimens in the Andaman Islands by Major Christophers is just short of final proof of their culpability.

[1] *A. maculatus* has since been found.

Table 7.3 Anophelines of South and East Asia

Species	India	Malaya	Borneo	Andamans	Sumatra	Formosa	Philippines
M. rossii	+	+		+	+	+	+
M. ludlowi	+	+	+	+	+		+
M. aitkeni	+	+		+			
M. tesselatus	+	+	+	+	+		
M. leucosphyrus	+	+	+	+	+		
Myz. sinensis	+	+	+	+	+	+	+
Myz. barbirostris	+	+	+	+	+		+
Myz. albotaeniatus		+	+		+		
Myz. kochii	+	+	+		+	+	+
M. albirostris	+	+		+	+		
N. fuliginosus	+	+		+			
Myz. umbrosus		+	+				
L. asiaticus		+					
M. aurirostris		+					
P. watsoni		+					
N. maculatus	+	+	+		+	+	+
N. karwari	+	+				+	+
N. listoni	+					+	+
N. species						+	
N. annulipes						+	
Myz. pseudobarbirostris							+
Steth. pallidus							+
N. philippinensis							+
N. wellingtonianus		+					
A. brevipalpis, n.s.		+	+				

7.4 The distribution of *Anopheles* in South and East Asia

It may be useful if I give here a list of the names and distribution of the *Anopheles* of South and East Asia. It is over fifty years since Alfred Russell Wallace returned from the Malaya Archipelago with 125,660 specimens of natural history. For eight years he had travelled from place to place, often enduring great hardship and privation. But these years made a great naturalist, and gave the world a wealth of scientific knowledge. Among the many interesting discoveries he made was the relationship which existed between the various islands of the Archipelago and the continents of Asia and Australia. He showed how the islands could be classed in three great groups: one which belonged to and, at one time, formed part of Asia; one to Australia; and a third group, consisting of islands formed by volcanic action, which were not continental in origin, although they may have been connected for periods with one or other continent. He proved this by showing how the various species of animals were distributed.

We are far from having anything like a complete knowledge of the mosquitoes of the Archipelago and the adjacent countries; but already we know something. From the table it will be seen that the Bornean group contain all the common mosquitoes of the Malay Peninsula, with the curious exception of *A. rossii*. It seems impossible that Dr Roper, who has made and identified (confirmed by Mr Edwards of the British Museum) the collection, can have missed *A. rossii*, if it is as common as it is in the Peninsula. *A. umbrosus*, found in the Peninsula, is also found in Borneo. This common mosquito population is a further proof of what Wallace discovered, that Borneo had been originally part of the continent of Asia.

We have seen, too, that in the south of Formosa a number of species exist, but that *A. rossii*, and presumably the others, except *A. sinensis*, do not spread beyond 24°N. lat. In Japan the only species I saw at the Imperial Research Institute was *A. sinensis*, and as malaria, due to the benign para sites, is found in Japan, this mosquito probably acts as a carrier of these forms of the disease. There is, however, strong evidence that it does not carry malignant or tropical malaria. Of Java, I believe nothing has been published of the relationship of the *Anopheles* to the distribution of malaria, except the papers of Dr De Vogel on *A. rossii*. It seems to me that from an investigation of the malaria in the islands of the Malay Archipelago much valuable information may be obtained.

Research cannot be confined to a laboratory; much knowledge can be obtained only in the field, and to the sanitarian the field should be a laboratory. If it is true that he cannot alter the conditions of his experiments, and so test the truth of his conclusions; he may, however, move to another place where the conditions are different, and there confirm or revise his previous conclusions. Thus to the sanitarian the world becomes a laboratory, and his experiments are carried out on a colossal scale. In the almost innumerable islands of the Archipelago, some may be found with particular groups of *Anopheles*, and by studying these groups and their relationship to malaria, it appears to me that information of great value may be obtained easily which elsewhere would be got only with extreme difficulty, if at all.

8. Panama: history and overview

8.1 History

My visit to Panama in 1913 was the accomplishment of a long-cherished design. At Panama, the American engineers could claim they had carried out "the most formidable engineering feat which had hitherto been attempted," while the sanitary work had been recognised by the whole world as the greatest achievement it had seen. Before the Americans came to Panama, it had been pre-eminently a land of failure, which the boldest had been unable to turn to success, while death had haunted them at every step. Time and again, Sir Francis Drake had raided the Isthmus and the Spanish Main. His deeds stir the most sluggish imagination. Yet the evil spirit of the place, in one voyage slew half his crew, not sparing even his own brother, and later on it claimed Drake himself; for he died from dysentery in 1595, and was buried at sea off Puerto Bello.

Morgan's raid across the Isthmus, when he razed the city of Panama to the ground, was a bold exploit. Perhaps it can be called a success, since the city was never rebuilt on the same site; but it can hardly be claimed as a great constructive effort. Even William Paterson, the Scotsman who founded the Bank of England, failed in the Isthmus of Panama. His colony on Darien lasted only two years, when the few who had escaped death from disease and war were only too glad to return to Scotland.

No idea had lured men to destruction more successfully than the spirit of the Isthmus. Intended as it was by Nature to be one of the two great highways of the world, men had fought and struggled for its possession, too often only to find themselves swallowed up by the monster some of whose many mouths are called yellow fever, malaria, and dysentery. The Spaniards made a survey for a canal, but came to the conclusion it could not be constructed, and contented themselves with a cobble road. Over it came all the treasures of Peru. But with the discovery of gold in California in 1849, and the development of the western states of North America, something more was necessary, and in 1855 a railway was completed, at no small cost of both lives and money. Later still, with the discovery of oil in California, an 8-inch pipeline was laid down beside the railway. Through it oil was pumped from Californian oil ships lying at Panama to ships at Colon ready to take it to New York and the Eastern States. This saved the oil-ships from the long and dangerous passage round the Horn.

But the call for a highway that would allow ships themselves to pass through from the one ocean to the other became more urgent, and in 1881 de Lesseps began the Canal he was not to see finished. His failure was, no doubt in part, due to extravagance; but

those who know most of how quickly costs mount up when disease dogs an enterprise in the tropics, will, I am confident, be the most lenient in their judgement on the great engineer. But when all excuses have been made, the French attempt was a gigantic failure, for it was the utter collapse of a stupendous work. In thirteen years they had not succeeded in completing even one half of the work on their canal, and that the easier half; while no less than $260,000,000 had been spent, and the cost in lives had been on an equally large scale. Their failure was enough to deter any but the men of a great nation determined to succeed, from resuming the work.

8.1.1 Why the Americans began the Canal. To the commercial men of America the canal had always appealed. By it the ports and states of the East and West would be joined by an easy line of communication. To send goods from East to West, or vice versa, meant either a long and expensive journey by train across the continent, or an even longer, much more dangerous, and no less expensive journey by ship round the Horn. By either route the freights were prohibitive for many articles. A canal would give a short sea route between American ports, and it would also bring many American ports much nearer to European and Asian ports. Nevertheless, although the advantages to American trade were so apparent, it is doubtful if by themselves they would have induced the American Government to take up the work after the French failure.

But in 1900 an incident in the Spanish-American war stirred the nation to its depths, and crystallised in its mind the determination to build the Canal. The war began when the battleship *Maine* was blown up in Havana harbour. To replace her, the new battleship *Oregon*, then at San Francisco, was ordered to join the fleet off Cuba. Had there been a canal, she could have done this easily and quickly. As it was, she had to perform the extra 8000 mile voyage round Cape Horn at full speed, with the risk of falling in with the enemy's fleet on her arrival at the seat of war. For nearly a month, in those days before wireless telegraphy, the nation waited in breathless suspense for news of the ship. Every American was asking himself, Would she escape? Would she fall into the hands of the enemy and share the fate of the *Maine*? That month of suspense decided the question of the Canal. There must be a canal. It was necessary for safety. Without it two fleets must be kept, one in each ocean. And that is why the Canal is being built by the War Department of the United States of America.

8.1.2 Preparation for the Labour Force. There were political difficulties to be overcome before the work could be begun; but the revolution whereby the State of Panama broke away from the Columbian federation, proclaimed itself a separate republic, and placed itself under the protection of the United States, smoothed the way for the work. Even then, however, the Americans did not rush a large labour force on to the Canal at once. They realized how much disease had contributed to the French failure, and they sent Colonel Gorgas, who had won his spurs in ridding Havana of yellow fever, to make the Canal zone habitable. It was well they did so, for when after eighteen months sanitary work, the staff and labourers began to arrive in numbers, a fierce outburst of disease occurred. Yellow fever spared neither high nor low, and, for a time, work on the Canal had partly to be abandoned. The Canal Commission could not work in harmony;

and, as I heard Colonel Gorgas tell a Washington audience, the executive asked for his (Colonel Gorgas') removal. They wanted a "practical man," not one who wasted time and money in fighting mosquitoes.

This really was the critical moment in the history of the Canal when in American hands. I wonder how many countries would at that time have given the right decision. The wrong decision would have meant failure. Had a "practical man" been sent to replace Colonel Gorgas and his unpractical methods, one need have no hesitation in saying that the Canal could never have been completed. There was, however, a strong man then as President of the United States; one who had seen Colonel Gorgas sweep yellow fever out of Havana for the first time in the history of 250 years. President Roosevelt not only supported Colonel Gorgas, but raised him to a seat on the Canal Commission. It was the obstructing engineer who was removed. Colonel Gorgas was given a free hand, and from that moment the health of those on the zone has steadily improved, and the work has been uninterrupted.

When President Roosevelt charged the first Commission with the great work, he called it, and rightly called it, "the most important and also the most formidable engineering feat which has been hitherto attempted." Not only have the Americans practically completed this great task, but they have given the world the finest example of sanitary work ever seen, and converted one of the most pestilential spots in the world into one which compares favourably with most places even in temperate zones. And to me it seems the real triumph of the Americans lies in the perfection of the whole Canal administration. It has been the high state of perfection of each branch of the administration which has given the success. And while competition both in work and play has been strongly encouraged between the component parts of this great organization, the triumph has been in subordinating that competition to the welfare of the whole, and in the creation of an admirable *esprit de corps* on the zone. The Canal builders have indeed built morally as well as physically a superstructure perfect in all its parts, and honourable to the builders.

8.2 My Failure to understand the Sanitary Work

It was now to be my privilege to see these great works. Of the engineering work I am not qualified to judge; but it was of paramount importance for me to understand the sanitary work. It is true that in the low coastal land of the Federated Malay States the health is as good as in Panama. Indeed, there is even less malaria in the Federated Malay States; but for our hill land, and certainly one-sixth of the peninsula is hill land, we could afford to neglect no method which promised success. I had studied a number of reports on the work in Panama. I had read how they destroyed the *Stegomyia* and the *Anopheles*; how they had provided water and sewage systems; how they had cleaned the towns, and screened the houses; how they had fed the people, and treated the sick. If we were to copy those methods a knowledge of the details was necessary. Success or failure in such things lies in the details. We have seen how the subsoil drainage failed at first in Kuala Lumpur through the neglect of detail.

After careful study of reports I was not satisfied I understood the full value of the different measures employed in Panama, and how much each had contributed to the successful result. As success was so manifest, and its importance so far-reaching, I had come to learn the details for myself. There were a thousand and one questions I wished to ask; but the most important related to malaria. It had been stated that in Panama *Anopheles* flew only 100 yards across open land, and so anti-larvae measures were carried out only for this distance. My experience in Malaya showed such a distance would have been of little use against our *Anopheles*; and I concluded the results in Panama must therefore depend to no small degree on the screening of houses. I was prepared to employ screening, oiling, or any other measure which would give a good result; but in practice I had been more and more drawn towards drainage.

From quinine I expected no permanent benefit. Against oiling I was prejudiced, partly because in running water a very concentrated poison, in combination with the oil, seemed to be necessary; but chiefly because I was not satisfied it would be applied with proper care. Writing in *Grenier's Rubber Annual* in 1911, I said:

> Theoretically this method, if used over an area of half a mile from a house, should abolish malaria. In practice, however, the result would depend entirely on the minute care with which the work was done and the nature of the poison used.
>
> When I recall the difficulty there has often been in obtaining a satisfactory administration of quinine, I have little confidence that a really efficient application of either oil or poison would take place. My experience with quinine has been that the efficiency of its administration depends entirely on the manager or assistant in charge. The disbelief of a new manager in the value of quinine is soon reflected in inefficient administration; or, while the manager may be convinced of its value, and imagines it is being given, the assistant who takes the muster either may neglect to give it at all, or give it in a perfunctory manner. These things I have seen time and again, although perhaps not so much in later years.
>
> And if such occurs with so simple an affair as the giving of a pill to each coolie at muster, I confess I regard with serious misgivings, the prospect of the periodical application of oil or poison to the almost innumerable tiny breeding places which occur in a ravine. For these reasons I have never been able to place a high value on oiling or poisoning as a practical measure on estates.

To screening I was more attracted, because, from an experiment at Jeram in 1902, it appeared to give excellent results. But it was in drainage alone, and for hill land in subsoil drainage, that I placed my faith, rather than in the combination of every known method as used in Panama. I thus wrote:

> It will be readily realized that, should it be possible to abolish malaria as completely from the hill land as from the flat by drainage alone, this will be an enormous advance on an elaborate system and organization which necessitates the screening of houses by mosquito-proof gauze, the oiling of pools, the administration of quinine, the catching of adult mosquitoes, etc. Men will then go about as in other parts of the world, doing nothing and taking nothing which they would not do or take elsewhere. To look for such a change in the conditions of life in hill land today is to make no greater demand on one's faith in science than to prophesy a similar improvement in flat land eight years ago. ...

For the system I am advocating it may at least be claimed that it offers at a reasonable cost a complete solution of the problem of keeping coolies on estates which have so far been intensely unhealthy. The only alternative system I know of is that put into practice at Panama. And while all must admire the Panama system as the finest sanitary organization ever seen, I trust it may never be required on estates.

It is an open secret that at one time the success of the engineering works at Panama was imperiled by the subordinate position of the Chief Sanitary Officer. President Roosevelt, however, grasped the situation, and Colonel Gorgas is now practically dictator, having full executive powers over all sanitary works. Everything is subordinate to the health of the Canal zone, because the American Government realizes that without healthy labour the Canal will never be completed.

And while the system has been a success in Panama, it is more than doubtful if it would be a success elsewhere. There is not an unlimited supply of either Roosevelts or Gorgases.

Few directors of Rubber Companies would care for the estate medical officer having the power of a Gorgas. And few medical officers (I certainly am not one) would care to be responsible for a Panama organization on an estate, even if armed with the sufficient authority, while without it the necessary organization and discipline would be impossible.

In a memorandum to the Malaria Advisory Board of the Federated Malay States on "The Prevention of Malaria in Rural Districts, and the need for further Experimental Work," I wrote:

Experiment No. 3

As it is very undesirable to neglect any measure which may be of value, I suggest that an experiment with mosquito-proof lines be tried. Mosquito-proofing, although expensive and requiring considerable supervision, has undoubted merits. This was proved at Jeram Hospital in the year 1902, and in 1907 Government granted $2000 to carry out a mosquito-proof experiment with coolie lines. I spent about $1000, but went on leave just as the experiment began. Unfortunately the experiment was neglected during my absence. On my return I could get no information, and the lines had been abandoned. I am still of the opinion such an experiment should be carried out, and from what I can learn the improved health in Panama must depend more on the mosquito-proofing than on any of the other measures carried out.

Panama

For while in Panama no expense or trouble has been spared to keep the labour healthy, and all the various anti-malarial methods are employed, drainage is done only for from 100 to 200 yards from buildings. Now we have abundant experience here to show that intense malaria will prevail at 200 yards from breeding places, even when quinine is given, and it appears to me that the mosquito-proofing must be *the* important measure.

I would like to point out here, in what respect the problem in Panama differs from that here, as I understand it. On this point I may shortly be able to place more information before the Board.

In Panama the object of the Government was to keep at its maximum of efficiency, for a few years, a body of men who numbered at the most 80,000. At the end of that period the labour force would be reduced to about 5000. There was everything then to be gained by keeping the labour at the maximum efficiency, for in this way the period of

construction would be shortened, the wages bill greatly reduced. The time would arrive when the Canal would be earning revenue, and the population would be brought down to a few thousands. Temporary measures, therefore, like oiling and mosquito catching, and semi-temporary measures like mosquito-proofing, were thus of much value; while permanent and expensive drainage, except in what would be the ultimate settlements, would be less necessary.

Even apart from this the total cost of all the medical charges was so trivial, when compared with the total cost of the Canal, and the importance of finishing the Canal, that they could well be neglected.

Further, as the whole area has been under a very strict discipline, it has been possible to exclude from the Canal zone any but those in good health, and generally to insist on the employees carrying out sanitary orders which with an ordinary native population would be very difficult, even if not impossible.

While, then, we all recognise the very high place in sanitary organization, if indeed the highest place must not be given to it, which the work at Panama takes, we also recognise that the organization was specially suited to a special occasion and to special work. We must also realise that the methods adopted are less suitable for an ordinary tropical population, and that the problem here differs materially from that in Panama.

Here, the population so far from diminishing after a short period of years, as it is doing in Panama, is increasing, and every year will still further increase it.

Here, again, it would be quite impossible to employ men to visit all houses daily to catch mosquitoes; and here, too, it is impossible, except in a very general way, to control the arrivals.

What we want to attain on the hill land is the power over malaria which we have on the flat land, the results of malaria prevention on which cannot be excelled—for the simple reason that abolition of the disease is complete—and are not equaled by Panama, either in efficiency or simplicity. And I hope to attain this perfect result on hill land by ascertaining as soon as possible the minimum area that must be drained to give it. And on this hill land I aim at placing the population in the same position as those on the flat land—namely, that they live in ordinary houses, and do and take nothing which other people do not do or take.

8.3 Criticism of Sanitary Work in Panama

The position had been still further obscured by criticisms from American and other sources. One critic, an American, whose name I do not give, for he is dead, was a man whose high scientific attainments were coupled with a singularly sincere and attractive nature. Of the honesty of his conviction there could be no question, and the impression he gave was that the labour force in Panama was under an iron discipline. He also stated deportation of the sick was carried out on an extensive scale; while entrance to the zone, except for men in robust health, was impossible.

There were, too, all sorts of other critics less qualified to speak than the foregoing. A few, and I am glad to say only a few, were evidently of the meaner sort, who cannot see others successful without suffering from spleen. They damned with faint praise. Other criticisms were obviously made in an honest spirit, but were no less incorrect and unjust to the Sanitary Staff of Panama. Such is Mr Foster Fraser's remark, that "if

you picked your men, you could prove the most fever-soaked swamp in the world was the healthiest spot on earth."

There is much less excuse for Mr Logan Marshall, when he writes:[1]

> The fact that medical services are entirely free, and that removal to a hospital is compulsory on the part of the attending physician, has much to do with the excellent conditions of health maintained there. It must be confessed, however, that in spite of all these precautions malaria still exists upon the Isthmus, and must be regarded as a serious problem, the only solution of which is the entire extermination of the *Anopheles* mosquito. The Canal operating forces must continue to live in screened houses, take quinine in large quantities, remain indoors at night, and continue the various precautions which have been adopted.

Mr Marshall, if he has really been to the Canal zone, ought to have seen for himself that most of these statements are incorrect. How he comes to say the Canal operating forces must continue to "remain indoors at night," is utterly beyond my comprehension, and absolutely incorrect. The fact is that on the Canal zone people go out of and into their houses as they do in other countries, and with exactly the same freedom; that practically no one takes quinine unless he is ill, and that only a small percentage of the people live in screened houses.

8.4 First Impressions

Landing at Colon, I took a quick walk round the town. It certainly was not much above the sea level, and had evidently been reclaimed. There were practically no mosquito-proof houses. No obvious *Anopheles* breeding places could be seen.

The town seemed a very ordinary place, not one in which I should have expected malaria. My first impression was, in fact, one of great disappointment. There seemed nothing of interest in Colon, and if the whole zone was like this my journey was a waste of time and money. Then I took train across to Panama City. At Gatun I could still see nothing of special interest. The swamps were all carefully drained. But when I reached Gorgona, and the series of settlements from there to Panama, I was completely puzzled. I saw crowds of houses with jungle and swamp within 100 yards and often less. They were not screened. Of oil barrels I saw a few. And the question pressed in on me: how could these people possibly keep healthy? They lived practically in jungle, with swamp oiled or drained, as I then believed, for only 100 yards round them. This was something quite beyond my experience and understanding, and when I reached Ancon I was still in complete darkness.

8.4.1 "Esprit de Corps" In due course I presented my letters of introduction to Colonel Goethals, chairman and chief engineer, and to Colonel Phillips, who was acting for Colonel Gorgas. From these gentlemen and the staff of the Sanitary Department I received every kindness and assistance. Major Noble, the acting chief sanitary inspector, was kind enough to arrange for me to see everything that I expressed the slightest desire

[1] *The Story of the Panama Canal*, by Logan Marshall, p. 146

to see. Dr S. T. Darling, the chief of the Board of Health Laboratory, placed a room in his laboratory at my disposal, and gave me every assistance possible.

The sanitary inspectors at each of the stations were equally kind, and took me to all the places of special interest. In addition they were of the greatest help to me in getting to places which, from the lie of the land, would, I thought, present special difficulties to the sanitarian. And as I got to know the staff, what I appreciated most was their kindness in discussing the whole question so freely, pointing out what was good and what they thought could be done better. The tone of the Department was admirable. A false modesty which would have belittled the work, or made them pretend they were unconscious of its merits, would have been no less offensive than bragging of its greatness.

There was a singularly happy spirit in the Department, too, which made men strive to do their best and improve their methods, yet which never for a moment made them forget their esprit de corps and the welfare of the zone. And this spirit was there, not because the greatness of the work operated on the workers and raised them to its high level. The source was in the chief, whose spirit pervaded the Department and made it great.

8.4.2 Historical significance of the work. The greatness of the work was derived from the builders; they were its inspiration. As from day to day I saw more and more of this vast undertaking, learned to appreciate what it was, to understand the difficulties, to feel something of the spirit which had overcome them; and as I thought how on the completion of the Canal this organization of builders would soon melt away, would cease to be a living demonstration, would become only a lesson in history, and one perhaps only imperfectly understood, I determined to spare no effort to master its details, that I might explain them to others. That I can do it justice, I cannot pretend to hope. I do hope that on the completion of the Canal a full history of the sanitary work will be written by Surgeon-General Gorgas and his staff on the zone, that every figure and record which has been accumulated will be published. Some have already been published. Others, as yet unpublished, I have seen, and allude to in this narrative. I believe that in these records we have observations and truths of infinite value to all tropical countries, and that their publication in full would be a lasting benefit to mankind. Until this has been done, perhaps, this and the other accounts of the work which have been published will help to give some idea of its nature and magnitude. For this account I can claim no merit except that it is written with a desire solely to tell the truth as I saw it. If the picture I draw conveys something of value to other fellow workers, it will have served its purpose. While if I succeed in doing even scant justice to the subject, I have no fear that to see themselves as others see them will be other than a pleasure to those who afforded me so much pleasure and profit in Panama. For I shall always regard it as one of the greatest privileges of my life that I saw the Panama Sanitary Department at work, and had the pleasure of meeting the men who composed it.

8.5 Yellow Fever and Malaria in the Past

8.5.1 Yellow Fever among the French. If we would understand what has been done for Panama by sanitation, a glance at its past medical history is essential, but it is not necessary to go very far back into its records; for at no time was the health worse than in the days of the French company. At that time there were large bodies of men, both Europeans and others, who were susceptible to both yellow fever and malaria; and such susceptible material is the very fuel for outbursts of disease. The Frenchmen working before Ross' discovery in 1897 of the transmission of malaria by the *Anopheles* mosquito, and of the discovery by Reed, Carrol, Lazear, and Agramonte—the American Yellow Fever Commission—in 1900 that the *Stegomyia* mosquito carried yellow fever, were therefore unaware of the danger oi these insects, and took no steps to destroy them. So both yellow fever and malaria had full play among the French labour force.

8.5.2 Highest officials not exempt. Neither *Anopheles* nor *Stegomyia* is the consequence of the presence of filth in the ordinary sense; indeed sewage pollution is unfavourable to both, so neither yellow fever nor malaria were confined to the less cleanly. Those who were best housed and best fed were quite as liable to contract the disease as those who lived in hovels. In a very striking passage Colonel Gorgas tells how, in order to eradicate yellow fever the ordinary sanitary measures were vigorously pushed in Havana in 1899 and 1900. They brought the general death rate down from 91.03 in 1898 to 33.67 and 24.40 in the two following years. Gorgas writes:[1]

> Smallpox had been entirely eradicated. But the great result at which we aimed seemed to be as far away as ever. Our sanitary measures, if they had any effect upon yellow fever, seemed to increase it. The cleanest and best built part of the city seemed to suffer most from the disease, and the best fed and best cared for part of the population was that which had the largest rate of deaths from yellow fever. It was the well-to-do class of Americans, and the highest officials on the staff of the governor general, who suffered out of all proportion to the rest of the population. In 1900, on the staff of the governor general, the chief quartermaster, the chief commissary, one of the aides, and one of the inspectors general, all died of yellow fever, and the preceding year the chief quartermaster and the chief ordnance officer had died.
>
> I mention this to show that the class of population whose surroundings were the best and as good as it was possible to make them, were suffering most from yellow fever. And the same can be said of the disease generally throughout the city. In 1898 there were 136 deaths; in 1899, 103; in 1900, 310. It looked very much as if the cleaner and better hygienically we got the city, the worse we were making yellow fever.

As Gorgas states elsewhere,[2] the French had had the same experience in Panama:

> We hear of many individual instances of heavy loss. The first French director, Mr Dingier, came to the Isthmus with his wife and three children. At the end of the first six months all had died of yellow fever except himself.
>
> One of the French engineers, who was still on the Isthmus when we arrived, stated that he came over with a party of seventeen young Frenchmen. In a month they had all

[1] "Disappearance of Yellow Fever from Havana, Cuba," by W. C. Gorgas, *Med. News*, New York, 1903, p. 11.
[2] *Sanitation at Panama*, Gorgas, p. 4.

> died of yellow fever except himself. The superintendent of the railroad brought to the Isthmus his three sisters; within a month they had all died of yellow fever. The Mother Superior of the sisters nursing in Ancon Hospital told me that she had come out with twenty-four sisters. Within a few years twenty-one had died, the most of yellow fever. Many other instances of this kind could be cited.

8.5.3 Doctors and Nurses Attacked. Doctors and nurses, although much more exposed to infection than the majority of the population, are notably exempt from attack of epidemic disease. But in Panama it was not so with yellow fever, as the foregoing shows.

8.5.4 Death rate of French Labourers. The death rate among the whole French labor force was also terrible. Colonel Gorgas says of it:[1] "From the best information which I can get, and which I consider accurate, I believe the French lost 22,189 labourers by death from 1881 to 1889. This would give a rate of something over 240 per thousand per year." And he generously adds: "I think it due to the French to say that we could not have done a bit better than they, if we had known no more of the cause of their tropical diseases than they did."

Indeed the experience of the Americans who came down to the Isthmus in the first few years of their occupation was by no means exhilarating.

8.5.5 The Americans begin in 1904. In July 1904, the first labour arrived to work at making the place fit for the larger force to follow. By 4th July 1905, a pipe water supply for Panama City was completed. The department then devoted its energies to the abolition of rainwater tanks, now no longer necessary, but formerly the only water supply of the city, and the chief breeding place of the *Stegomyia* mosquito. Yet despite this year's work a sharp outbreak of yellow fever occurred. From six [cases] in December 1904, it jumped to nineteen, fourteen, and eleven in the succeeding three months. Again, it seemed to show a predilection for high places, for of nine cases which occurred in April 1905, no less than seven "were among employees in the French Administration Building, which had become the headquarters of the Commission in Panama, where about three hundred Americans were engaged. When three of them died, a panic arose among Americans on the Isthmus, and all steamers outward bound were laden to the full capacity with frightened employees."

Further increases of the disease to thirty-three cases in May and sixty-two in June, particularly affecting the employees, "added to the panic, and nothing except lack of sailing accommodation prevented the scattering of the whole force." So writes Mr Bishop, the secretary of the Isthmian Canal Commission, who was on the zone at the time.[2]

Some may be inclined to point the finger of scorn at this panic. If there be such, they will not, I think, be those who have passed through the grave ordeal of a great epidemic disease. It is only veterans in any warfare who can stand unmoved as each day opens to show more and more blank files in the ranks. Nor should it be forgotten that the

[1] *Ibid.*, p. 5. [2] *The Panama Gateway*, p. 242.

Americans were under fire for the first time. But whatever is said of the 1905 panic, the subsequent brilliant record is sufficient to close the lips of the thoughtless scoffer.

8.5.6 The Last Yellow Fever Epidemic. It was an uphill fight.

> From March to September 1905, the commonest sight on the streets of Panama was some detachment of the fumigation brigade.
>
> The city was fumigated in sections once, then again, yet again, and in the fourth and supreme effort there was a general fumigation over the entire city at the same time. Tons upon tons of paper went to plaster up the crevices in the walls of houses, and some of the crevices in some of the houses would easily have admitted the historic barn door. The fumes of sulphur and pyrethrum were in constant ascent to the upper air, while all around a Pelee-like aspect prevailed. Those were trying days to the householder. He'd barely recovered from his last dose before men with ladders, buckets, and rolls of paper were again besieging his premises.
>
> It was a nip and tuck battle for three or four months in 1905. At one time the outlook might be said to have looked dubious, but the leader of the sanitary forces never wavered in his belief in his theory, and the contest went steadily on.
>
> At last, towards the end of 1905, results began to be apparent. Sources of infection were destroyed, and on 11th November of that year occurred the last case of yellow fever in Panama. The last case in Colon was reported on 17th May 1906.[1]

8.6 Malaria

With malaria, too, the fight was a tough one. It lasted much longer; but as the rate of mortality was not so high, and death did not as a rule occur so suddenly, it had a less demoralising effect on the population than yellow fever. The maximum malaria admission rate was 821 per 1000 in 1906.

But this entirely fails to give an idea of what the rate would have been had nothing been done to reduce the number of *Anopheles* in the thirty months previous to the end of 1906. For before the end of that year, 1,758,953 lineal feet[2] of ditches had been cleared out, 231,365 feet[3] of new ditches cut, and 14,468,968 square yards[4] of brush cleared. This must have affected the malaria rate very materially, quite apart from the screening of the houses and distribution of quinine and the oiling, which had also been carried out very thoroughly.

A truer idea of what malaria would have been can be got from the fact that among the 253 U.S. troops stationed at Camp Eliot in 1906, there were 796 cases of malaria, giving an admission rate for malaria of 3315 per 1000. And of 450 men stationed at Mount Hope "taking ten grains of quinine daily," nearly 100 percent developed malaria either while on the Isthmus or within a month after leaving. As we have seen similarly high rates in the Federated Malay States, we can easily understand this.

With the sharpshooters picking off the officers, with the fatalities among the men higher than occur in ordinary warfare, while every reinforcement of the army aggravated the mortality by introducing more susceptible material, we can understand why it was necessary to abandon operations on the Canal for a time in 1906 until the san-

[1] *Canal Zone Pilot*, 330. [2] 333.14 miles [3] 43.82 miles [4] 2,989.45 acres

itary conditions could be still further improved. That temporary abandonment was necessary in 1906, even after the eighteen months' preliminary sanitation from July 1904 to December 1905, during which an enormous amount of sanitary work was done, including the provision of water supplies for the two chief towns and most of the subsidiary stations, demonstrates beyond question that it would have been impossible ever to establish the large labour force necessary to construct the Canal without the strenuous work of the Sanitary Department.

9. Panama: sanitary provisions and local conditions

9.1 The organization of the department of sanitation

9.1.1 Significance of the name. Even in its name, the Sanitary Department of Panama is a landmark in medical history, and indicates an important change in the official attitude to disease. Hitherto the chief officer of the department which deals with health in a community has been styled a medical officer, and his first duty has been to care for the sick. It is true that he has been expected to have some regard for sanitation, doing as much as he could with the little voted for the purpose. Sanitation has been, however, regarded mainly as a "bottomless abyss" into which money could be poured, usually without much result. That it could be reproductive expenditure has not yet been grasped by most governments. This attitude was in no small way due to the failure of sanitary measures to control many of the most important diseases in the tropics.

It is true, cholera had almost been stopped by good water supplies in many places; but yellow fever and malaria fever defied all efforts of the sanitarian. But the American Government had, already by 1904, grasped the important fact that success in building the Canal depended on the success of the sanitarian in eliminating yellow fever and malaria, etc.; and to emphasise the importance of the preventative work, the department was called the Department of Sanitation.

The experiments which proved that yellow fever was conveyed by the *Stegomyia* mosquito were made as late as between June 1900 and February 1901. Yet by the 15th February 1901 General Leonard Wood had issued an order, putting into force the regulations for fighting yellow fever by destroying the mosquito; and the last case of the disease in Havana occurred in September 1901. About three years later, when arrangements were being made to construct the Canal, President Roosevelt, who had been in Cuba and knew the value of the work done there, instructed the first Canal Commission to give special attention to sanitation, and to secure the best medical experts attainable for this purpose; saying further, in a letter to the secretary, that "it is the belief of those who have noted the successful results secured by our army in Cuba in the obliteration of yellow fever in that island, that it is entirely feasible to banish the diseases that have hitherto caused most mortality on the Isthmus."

The promptitude with which General Leonard Wood utilised and profited by the scientific discovery made by the American Commission in Havana in 1901 is very extraordinary indeed, when compared with the attitude of many other governments towards similar problems. Within a couple of months of the conclusion of the experiments, the Americans had in full swing operations against the mosquito throughout the city; while

when the critical moment in the history of the Canal came, the President of the United States at once brushed aside the engineer who was obstructing the sanitarian.

9.1.2 The three sub-departments. Colonel (now Surgeon-General) Gorgas, the head of the department, is called the Chief Sanitary Officer. Under him are Mr Le Prince, the Chief Sanitary Inspector, who is in charge of all the "preventive" work; Colonel Mason in charge of all the hospitals and dispensaries, i.e., of the treatment of the sick; and Dr Darling, Chief of the Board of Health Laboratory, who does most of the scientific work required by the other two sub-departments.

These three sub-departments are entirely independent of each other, but working in harmony. Mr Le Prince is an engineer, and all his staff are or may be composed entirely of laymen. Colonel Mason's staff are physicians, surgeons, nurses, and all required for the hospitals. It is important, indeed of first importance, then, to grasp the fact that although inspired and directed by a medical man, the sanitary work which has made the construction of the Canal possible has been carried out by intelligent laymen, and not by medical men; and as will be seen later on, the success of the sanitary work has been due in no small measure to the keen interest taken in it by Mr Le Prince and his men, who have constantly striven to devise new and improve old methods of dealing with their foes.

While independent, the three sub-departments come into contact through the chief sanitary officer in the following ways: firstly, the hospital returns are sent to the chief sanitary inspector, who makes a special inquiry into the sanitary conditions if the amount of sickness in any station rises above the normal; and secondly, the district physicians make independent inspections of the sanitary conditions of premises, etc., and make recommendations, but are not allowed to give any orders to sanitary inspectors. Otherwise the sub-departments are distinct, and they work without the slightest friction. It is, consequently, possible to study each sub-department by itself.

9.2 Geography and climate of the Isthmus and Canal

9.2.1 Geography. Before going into details of the sanitary administration in the Isthmus of Panama, it will be convenient if I give a short description of the geographical conditions of the Canal zone and the Canal. A knowledge of this is essential to an understanding of the sanitary work.

Where the Isthmus is pierced by the Canal it runs almost east and west; and so the Canal, contrary to what one would expect, runs almost north and south, and its banks are always spoken of as the east or west bank, as the case may be. The latitude is approximately 9° north, and the longitude 80° west of Greenwich.

By the treaty with the Republic of Panama, the United States obtained in perpetuity a lease of a strip of land 5 miles wide on each side of the middle line of the Canal. This is called the Canal zone; and over it the Government of the United States has even greater control than it has over land in the States themselves, for the zone is really under the Department of War, which operates through the Isthmian Canal Commission. By the same treaty the capital of the republic, the city of Panama, on the Pacific coast, and the

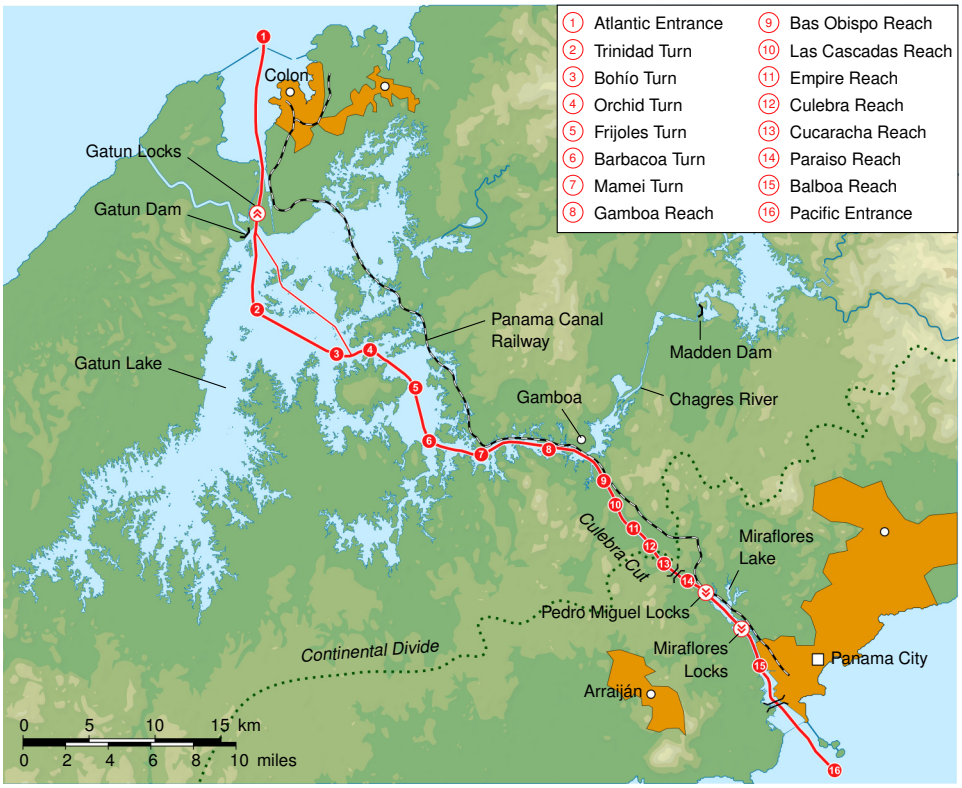


Figure 9.1 Map of the Isthmus of Panama. This map was adapted from a modern one found on `wikipedia.org`. The map shown in the original edition of this book can be found in the Appendix (see Section A.1).

town of Colon on the Caribbean Sea, are expressly excluded from American control, except in regard to sanitation.

The town of Colon is close to the Atlantic end of the Canal, and is indeed the terminal town on the Canal. But in order to give the United States proprietary rights over the docks and other works at the end of the Canal, a portion of Colon has been brought within the Canal zone. This is called the town of Cristobal. The boundary between the two is a well-made street. Colon and Cristobal are really one town, although the administration of the two is in different hands. Similarly, at the Pacific end of the zone, the city of Panama, the capital of the republic, is separated from the American town of Ancon only by a street. The end of the Canal is about a couple of miles from the city of Panama, and opens on the ocean at a place called La Boca. This name has been changed to Balboa, in honour of the discoverer of the Pacific. There are thus three place names within a couple of miles of each other at the Pacific end of the Canal, namely, Panama, Ancon, and Balboa; and two at the Atlantic end, Colon and Cristobal.

The Atlantic end of the Canal begins in the swamps of Limon Bay, for here, as in the rest of the Gulf of Mexico, there is practically no rise and fall of the tide, and the

land shades off into the sea by means of an extensive swamp. Running for some 7 miles through this low-lying land and swamp, and of course on sea level, the Canal reaches Gatun, where, by means of a flight of three locks, ships are raised to a lake 85 feet above sea level. The lake is formed by an immense dam nearly 1½ miles long, ½ mile wide, and over 100 feet high. This enormous dam holds up the waters of several rivers, the chief of which is the Chagres. At Gatun the scenery changes: from a swamp, we pass to a lake 164 square miles in extent surrounded by hills, studded with islands, and with branches running for miles up the valleys of the submerged rivers. Not only have rivers been submerged, but so, too, have disappeared the old line of the Panama railway, and the villages of Tabernilla, Mitchelville, and old Frijoles. By means of this dam sufficient water has been obtained to operate the locks, and by its great extent the dangerous floods which swell the Chagres in the rainy season have been rendered harmless, indeed have been stored ready for use in the dry season.

Ships will be able to steam through the lake at full speed, until they reach the beginning of the Culebra Cut. The Cut begins at Gamboa, extends for a distance of 9 miles, and ends at Pedro Miguel. The Cut is really part of the Gatun Lake, the waters of which thus carry ships over the Isthmian divide or watershed: it has a minimum bottom width of 300 feet; the average depth of the excavation is 120 feet; while at Gold Hill, where the Cut crosses the watershed, the bottom of the Canal is 300 feet below the original ground level. Someone has called the Cut a great valley, and the idea is quite a happy one. Along the valley are a series of stations occupied by the Canal employees and others. They are called in order from north to south, San Pablo, Bas Obispo, Las Cascadas, Empire, Culebra, Paraiso, and Pedro Miguel. With the exception of the two last-named all are on the west bank of the Canal.

At Pedro Miguel ships will pass from the great Cut with its high banks, through one lock, into a lake formed by damming the Rio Grande. This lake when filled with water will be 2 miles long, and about 1 mile in width, and will be entirely artificial. When it is filled with water much of what is now Pedro Miguel will disappear. The hills round the lake run to about 500 feet in height.

Passing the Miraflores Lake (for that will be its name), steamers will descend by means of two locks to the Pacific level. The Canal here follows the valley of the Rio Grande, and for the most part runs through a mangrove swamp. At the locks is the station called Miraflores, and about 2 miles farther on is Corozal, situated, not on the Canal, but on the solid land forming the shore of the mangrove swamp through which the Canal runs. Another 3 miles brings the Canal to Balboa, the Pacific terminus, where the tidal range is 20 feet, a marked contrast to that at the Atlantic end of the Canal, where it is only about 20 inches.

The Canal thus passes through several different kinds of country; first, low-lying, almost undrainable swamp, then through a high-level lake, then through a deep cutting, and after a short distance in a second lake into a mangrove swamp, which, however, is much more drainable than that at the Atlantic end. The sanitary authorities had, therefore, a number of different conditions to deal with, and it was my object to ascertain how each of the different situations had been met.

9.2.2 Climate. Like other places near to the equator where the sea is not far distant, the Isthmus of Panama is not excessively hot. The maximum temperature recorded at Ancon is 97°F. The mean maximum, however, for the year 1911 was only 86.8, and the mean minimum 71.6. These records are from Ancon. The maximum temperatures are about 5° lower than in the Federated Malay States.

With some misgiving I abandoned my "topee," and wore a felt hat (the inner part of a "double Terai"); for everyone wore felt hats, and topees are unknown. For a couple of days I was rather unhappy at times when in the full force of the sun; but the unhappiness was entirely due to the feeling that there was danger from abandoning the topee. There was no physical discomfort; indeed it was a great comfort to wear so light a hat in place of a heavy sun hat; and after a couple of days I felt the change was entirely for the better. As during my stay on the Isthmus I was walking about almost all day, stooping down searching for larvae, my exposure to the sun was almost as great as it could be, and was accompanied by considerable physical exertion. It may be prejudice, but I do not think I could do the same thing in Malaya. Certainly I have suffered from severe headache within a few minutes when exposed to the sun in the Federated Malay States.

I am inclined to think that, on the whole, the physical conditions as regards actual temperature, are more favourable to the white race in Panama than they are in Malaya; but as will be seen later on, the conditions which favour the breeding of malaria-carrying *Anopheles* are such that had the insects not been kept under control, the health of the labour would have been practically as bad as it could possibly be.

9.2.3 Rainfall. With regard to rainfall, the records show that the Atlantic side of the Isthmus is much wetter than the Pacific. The average rainfall per annum at Colon for forty-one years is 129.59 inches, while the average of four years for Porto Bello, which is about 20 miles along the coast, is 173.02. Porto Bello has a record of 2.48 inches in five minutes. There is a steady diminution of the rainfall from Colon to Ancon, where the average for fourteen years is 71.23 inches; while 10 miles out in the Bay of Panama, at the Island of Taboga, its amount has decreased, so I was informed, to between 40 and 50 inches.

9.3 Sanitary Inspection

9.3.1 Division into Sanitary Districts. The length of the Canal zone is approximately 50 miles, and its width 10 miles. As, however, only a portion of this whole area is occupied by the Commission employees, the Sanitary Department has confined its operations to the portions actually inhabited. For the purposes of sanitation, the whole zone except Cristobal is under Mr Le Prince, the chief sanitary inspector. It was divided originally into seventeen districts, but at the time of my visit Tabernilla and Mitchelville had been abandoned, having been covered by the rising waters of Lake Gatun. On the other hand, Monte Lirio and Frijoles were new stations on the relocated railway line.

Table 9.1 gives the number of sanitary inspectors in each district or station, the area of the station, the length of the ditches in miles, and the acreage of grass constantly cut in 1912.

Table 9.1 Sanitary districts in Panama

District	Number of inspectors	Area (sq. miles)	Ditches (miles)	Grass area cut regularly (acres)
Ancon	1	3.00	–	43.01[1]
Balboa	1	4.50	24.97	107.76[2]
Corozal	1	2.30	23.53	273.50
Miraflores	2	3.25	19.77	143.33
Pedro Miguel[3,4]	2	3.20	19.19	37.68
Paraiso[4]	1	1.21	19.74	203.88
Culebra[4]	2	1.80	35.52	419.82
Empire[4]	2	1.85	61.49	463.88
Las Cascadas[4]	1	1.00	9.93	127.98
Bas Obispo[4]	1	4.00	3.18	95.87
Matachin and San Pablo	2	9.00	6.38	60.78
Gorgona[5]	1	0.63	13.32	93.05
Frijoles and Monte Lirio[6]	1	0.50	–	–
Gatun	4	11.00	31.37	422.22
Porto Bello	1	0.50	1.40	–
East of Canal	–	2.30	–	–
Colon and Cristobal	–	2.40	43.18	359.40
Panama	–	1.00	–	–
Total	23	53.24	323.30	2854.16

[1] Submerged area not included
[2] Hospital grounds not included
[3] Additional 61.25 acres of grass in unplotted area
[4] These stations are on the Culebra cut
[5] These stations replace Tabernilla and Mitchelville

Each of these districts is under a sanitary inspector, who has one or more assistant inspectors, according to the amount of work to be done. The districts are further grouped into two divisions, each of which is placed under a divisional inspector. His duty consists of inspecting, advising, and reporting; he has power to give an order to a sanitary inspector only in an emergency, and when he does so “a report must be made to the chief sanitary inspector covering the matter.”

Table 9.2 Personnel of the Sanitary Department in the Canal Zone

Role	Number
chief sanitary inspector	1
assistant chief sanitary inspector	1
division inspectors	2
inspector entomologist[1]	1
inspectors	26[2]
foremen	18
labourers	226

[1] post since abolished—M. W.
[2] this allows for leave—M. W.

For much of the following information I am indebted to Dr A. J. Orenstein's paper, "Sanitary Inspection of the Canal Zone."[1] Dr Orenstein occupied for a time the post of assistant chief sanitary inspector.

The personnel of the division of zone sanitation is listed in Table 9.2. Each of the twenty-three inspectors on the zone has, therefore, an average of 2.16 square miles (or 1382.40 acres) under his care, and to carry out his instructions has 10.6 men under him. On his 2 square miles there are 11.1 miles of ditches to be oiled and upkept; and practically one-thirteenth of the area is under grass, which is constantly cut by the Quartermaster's Department at the expense of the Sanitation Department.

The chief sanitary inspector and his deputies derive their powers from Act No. 8, section 20, of the Canal Zone Laws. It is:

> The Chief Sanitary Inspector shall have direct charge, management, and control of all work performed or entered upon within the Canal Zone for the prevention or suppression of diseases. He shall be charged with the duty of securing the enforcement of all sanitary regulations, and perform such other duties appertaining to his position as may be required of him by the Chief Sanitary Officer, the Governor of the Canal Zone, of the Isthmian Canal Commission.

9.3.2 Guidelines for sanitary inspectors. A Manual of Instructions for sanitary inspectors has been compiled. It …

> … sets forth briefly the essential things necessary to the Sanitary Inspectors for the efficient performance of their work, such as methods of inspection, methods of making out the routine and special reports, building and screening regulations, construction of pit and pail closets, night soil disposal, fumigation, disinfection, etc. In addition the Inspectors are required to be familiar with the appearance, life-history, and habits of Anophelines, *Stegomyia*, and Culicines. They are expected to be able to distinguish these species in their larval and adult forms, and to be familiar with the methods of mosquito

[1] *American Journal of Public Health*, March 1912.

reduction in use here. Inspectors are also required to be familiar with the breeding habits of the house fly, and the usual methods of extermination of flies.[1]

The whole tone of the *Manual* is admirable, as will be gathered from the following sections in Chapter I on General Instructions:

> The conditions of life and work on the Isthmus impose upon the Sanitary Inspector duties exceedingly varied in character. These duties embrace every phase of sanitation, involving not only the health, but the comfort, contentment, and general well-being of the people of his district. He must organise and carry on vigorously, persistently, and smoothly a work of vast importance to the community. His work must be carefully planned, his labours well disciplined, his office work promptly and accurately performed, his expenses closely scrutinized, and his property carefully used and guarded. In his relations to the people of his station he must sustain the dignity of his position by a gentlemanly bearing, universal courtesy, moderation, tact, and patience, which will enable him to carry out his duties with firmness, impartiality, and justice to all, with the least friction, and without incurrence of the ill-will of anyone.
>
> He will obtain the confidence and respect of the people, seek the acquaintance and maintain amicable relations with the heads of all departments, and especially with the physicians of his district, to whom he will extend all the courtesies and facilities at his command in furtherance of their work.
>
> No actual clash, or disagreement with, or inattention to the requests of the district physicians of this department will receive consideration in this office. Comply with requests, and enter protests later. The same holds good with the officials of other departments, to the effect that there will be no clash; the Inspector, however, is allowed a wider range of latitude in his judgment as to what course he should pursue.
>
> It is the policy of this office to give District Sanitary Inspectors wide latitude in the administration of their districts, and the management of all affairs pertaining thereto. They will at all times have the support and full backing of this office in the faithful performance of their duties. Their recommendations and suggestions are sought, and will receive careful consideration.
>
> Sanitary Inspectors should use every reasonable endeavour to secure compliance with the Sanitary Regulations by obtaining the cooperation and goodwill of the people. The advancement of sanitation is a matter of education rather than force. Sanitary Inspectors should also remember that sanitary regulations often cause considerable temporary inconvenience to the public, and they should endeavour to secure cooperation of the public by pointing out that the benefits to be derived from aiding the Sanitary Department are of far more importance than the inconvenience caused.

The supreme importance of the anti-mosquito work will be gathered from Chapter V. of the Manual. It deals with inspections:

(1) Inspectors in charge of districts may assign certain sections of the district to their assistants; but the Inspector in charge will be held responsible for the whole district, and must assure himself by personal inspection that conditions are satisfactory. It is directed that the Inspector in charge shall inspect every part of their district at least once a week.

(2) In the order of importance the sanitary inspections consist of:

[1] Dr. Orenstein's paper.

1. Inspections to detect and remedy conditions favourable to *Anopheles* breeding.
2. Inspection to detect and remedy conditions favourable to *Aedes (Stegomyia) calopus* and Culicine breeding.
3. General sanitation.

(3) All streams, ditches, pools, marshes, and other areas where *Anopheles* might breed, should be inspected at least once a week, and the presence or absence of larvae noted. The inspection must include an actual search for larvae, and the desk diary must contain an entry showing when and where such search was made, and what was found. During these inspections the necessity for remedial works will be noted. More or less permanent breeding areas must be designated by a number, and this number must be used in all records and correspondence relating to the areas. The finding of pupae in a sanitary district will be considered as neglect on the part of the Inspector.

(4) District Sanitary Inspectors shall from time to time inspect the dwellings in their districts for the presence of adult *Anopheles*. They should also follow up the work of the mosquito catchers, to satisfy themselves that this very important work is being thoroughly done.

(5) District Sanitary Inspectors will make a weekly inspection of all premises for possible breeding places of the *Aedes (Stegomyia) calopus*. All rules regarding the screening of containers, prohibition of water storing within 300 feet of a public supply, and on premises supplied with water service, should be vigorously enforced. The carrying out of the regulation prohibiting eave gutters, except self-draining short gutters over doorways, must be insisted upon.

(6) Eave gutters on Government buildings found to be defective and holding water must be reported in writing to the Chief Sanitary Officer.

(7) There must be no *Aedes (Stegomyia) calopus* breeding in the Canal zone. Weekly inspections must be made of all Government quarters for defects in mosquito-proofing, methods of garbage collection, and general cleanliness of premises.

Weekly inspections must be made of all native houses, shops, bakeries, hotels, stables, stores, slaughter-houses, markets, and all other places where conditions dangerous to health or life may exist.

Weekly inspections must be made of all commissaries and Government messes, noting the sanitary conditions. Defects must be reported promptly in writing to the Chief Sanitary Inspector.

Section 8 deals with repairs to mosquito-proofed buildings; 9, with food unfit for use; 10, with the sale of beverages; 11, with building regulations; and the 12th and last section, with the safety of buildings.

Dr Orenstein also gives the anti-mosquito work first place, saying:[1]

The work done by the Division of Canal Sanitation may be classified in the order of its relative importance and magnitude into:

(a) Anti-malaria work.

(b) Anti-yellow fever work.

[1] *American Journal of Public Health*, 1912.

(c) Anti-plague work.

(d) Anti-typhoid and dysentery work.

(e) General sanitation.

> The work directed towards the control of malaria is relatively of most importance from the standpoint of the sanitary inspector, and it claims by far the largest portion of his time and effort, approximately two-thirds of the sanitary inspector's time being devoted to this work.

It has been my experience, too, that where malaria is present in a severe form, its control is the most important sanitary work which can be undertaken, and that other sanitary work shows practically no result until the malaria is controlled. I was, therefore, much interested to find the orders to the sanitary inspectors in Panama so clear on this important matter.

The work of the Sanitary Department may perhaps be most easily realized by my giving a record of what I saw from day to day on the zone. I was particularly anxious to study the breeding places of the chief malaria-carrying mosquitoes, namely, *A. albimanus* and *A. argyritarsis*, and to see how the various conditions in which water is found were dealt with. My visits to the different stations were not made in regular order. Often I accompanied Major Noble when he happened to have special work at a station, and by doing so I had the advantage of seeing how he dealt with such special questions as had arisen. Afterwards he was good enough to show me the whole station. On other days I visited stations along with the divisional and sanitary inspectors. During my stay I visited and walked over a large part of every station on the zone.

I propose here to describe what I saw, taking each station in the order of my visit rather than in geographical order.

10. Panama: visits to sanitary districts

10.1 Ancon and Balboa

The city of Panama and the town of Ancon are, as I said before, divided from each other only by a street. Ancon is built on the sides of Ancon Hill, which slopes off into the sea as a low rocky promontory; and on this is the city of Panama. On the east this promontory runs off into undulating land, called the Savannahs, well above the level of the sea; while on the west there is a mangrove swamp which curves to the north of Ancon Hill. So these towns are really cut off on the landward side by mangrove swamp. On the higher slopes of Ancon Hill are the Administration buildings and the hospital. The swamp below is being filled in. Originally the swamp was drained; but at the time of my visit the original drainage system had been obliterated by "filling" to a depth of about 6 feet. This will be an advantage ultimately; in the meantime, however, the area demands greater supervision, and an increased expenditure on oil.

The stone being "dumped" was from the Culebra Cut. Hard enough to require blasting in the Cut, when once exposed to the air it weathers very rapidly; and stone only a month out could often be kicked into a fine black powder. It is really a compressed volcanic ash. For a year or two it remains porous; then it becomes almost impervious to water, as the Department found to its cost after using it as a covering to the subsoil pipes.

Ancon was not the only place where the drainage had been obliterated by the engineers in disposing of the spoil from the Cut. When we remember that the material excavated from the Canal amounts to 212,000,000 cubic yards of earth, and that every additional yard this has to be conveyed adds to the cost of the Canal, we can understand the "dumps" must be numerous, and must affect to a considerable degree the physical and hydraulic conditions of the country. On the "dump" were fly-proof latrines for the labourers employed.

After visiting the larvicide factory, which is connected by rail with the railway system, and after examining some drains where the grass had been burnt off the sides, we walked across the new "filling" to the labourers' quarters, and examined a "range latrine." This is a trough latrine, flushed by siphon action; but, as during most of the day and night it is not used, water is saved by putting the siphon into action only at certain hours. We also inspected some of the subsoil drains, which are always covered by stone; and here, as shown in Figure 10.2, terminate under a cement cover to prevent damage to the railway track. Following the railway, we found it went off from the hill at a tangent direct for Sosa Hill, past the west side of which runs the Canal.

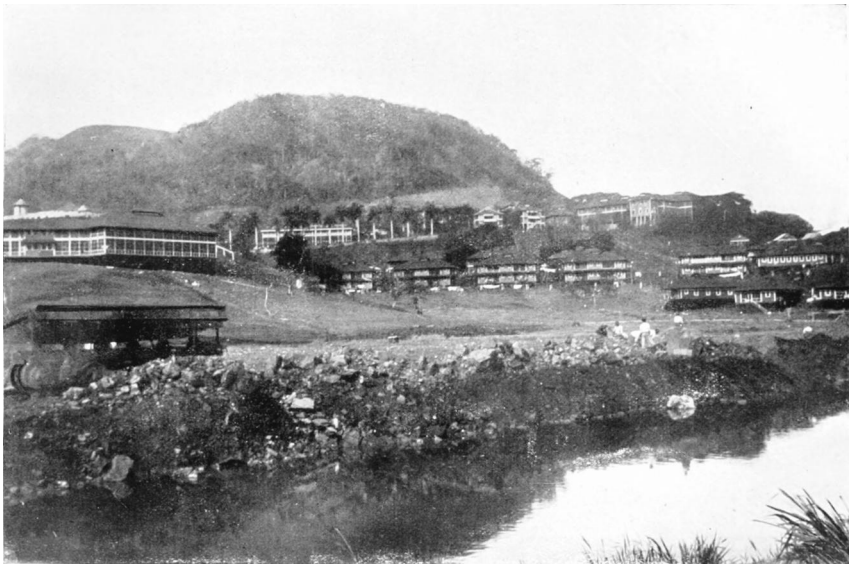


Figure 10.1 Ancon Hill. On the upper portion of the hillside is the Hospital. Below the hill the land was originally mangrove swamp, but it has been raised from time to time. At present further raising is being carried out, and a large pond has been created temporarily from the drainage system being destroyed.

Between Sosa Hill and Ancon Hill a bay of the mangrove swamp had been enclosed. Part of this had been filled with solid rock, but most of it was being filled hydraulically. There is a double advantage in employing this method here; for the pumps are removing mud from the site of the new docks, and are depositing it in the area that will ultimately become the site of the official quarters of the new port. The native town is to be built on the solid dump on the ocean side of Sosa Hill.

We then visited the dispensary, the commissary, and a kitchen and barracks, seeing on our way some water with the "iron rust" parasite. The labour force consists of Europeans, namely, Spaniards, who get 20 cents (gold) an hour, and of West Indian negroes, who get 10 cents (gold). They live in mosquito-proof quarters constructed of wood, and raised about 3 feet off the ground. The roof of each house is galvanized iron. It has no wooden ceiling, but has a jack roof, which is screened. Any spaces are caulked with oakum mixed with white lead, to prevent rats eating the oakum.

The "standee" bunks consist of an iron frame on which canvas is stretched. Periodically the frame and canvas are boiled, and the supports scorched, to kill bugs. But private clothing which is full of bugs is not disinfected, since the men strongly object to it. There are a few quarters subdivided for married men; but married men are not encouraged, with far-reaching consequences, of which we learn later on. Close by we saw the disinfection of the bunks carried out; they are boiled in an iron tank; the canvas is then scrubbed white, and dried in the sun.

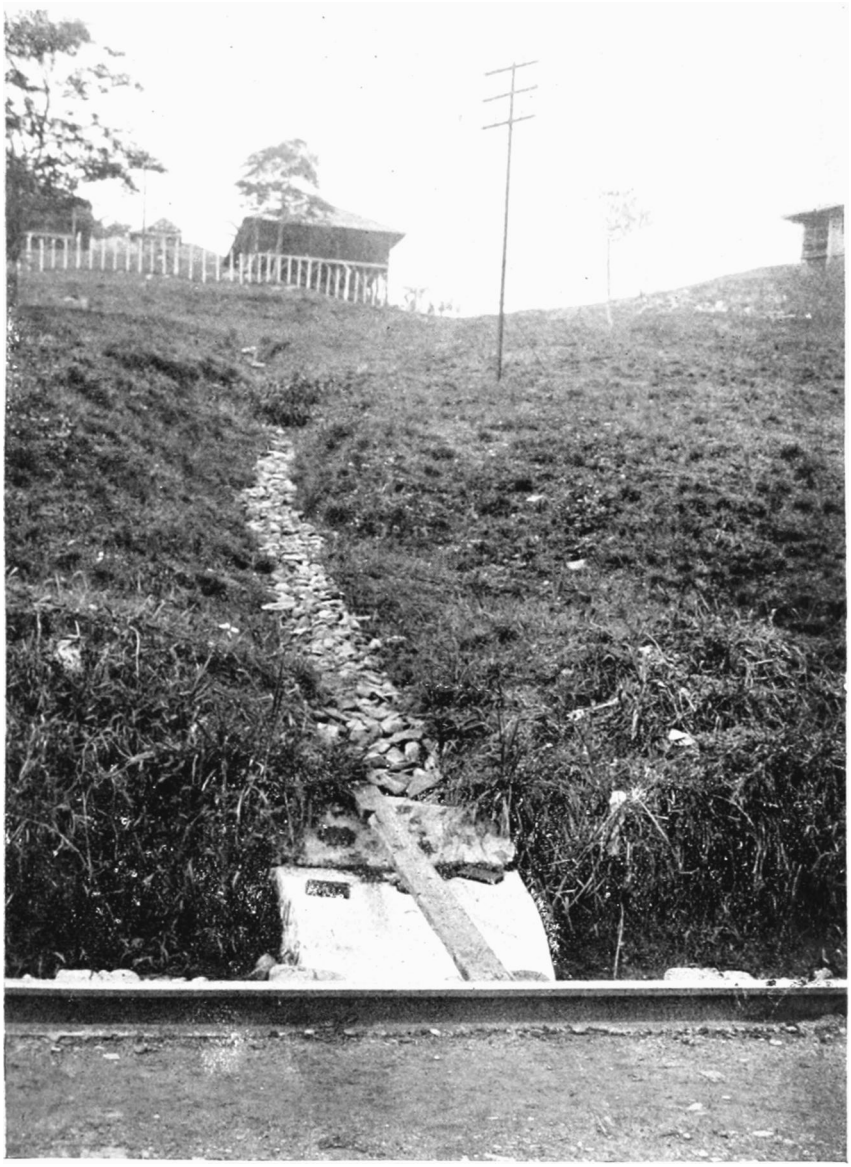


Figure 10.2 A Subsoil Drain covered by stones at Ancon. To prevent water from the pipe washing away the railway line, the end of the pipe discharges below and against a concrete covering.

10.2 Gatun

17th May 1913. To Gatun by the 6.50 a.m. train with Major Noble, in the hospital car which is attached to each train. At the station Mr Corrigan, the sanitary inspector of Gatun, met us; and as we left it I saw, for the first time, a species of ant that cuts up the leaves of plants into small pieces rather larger than confetti, and walks off with

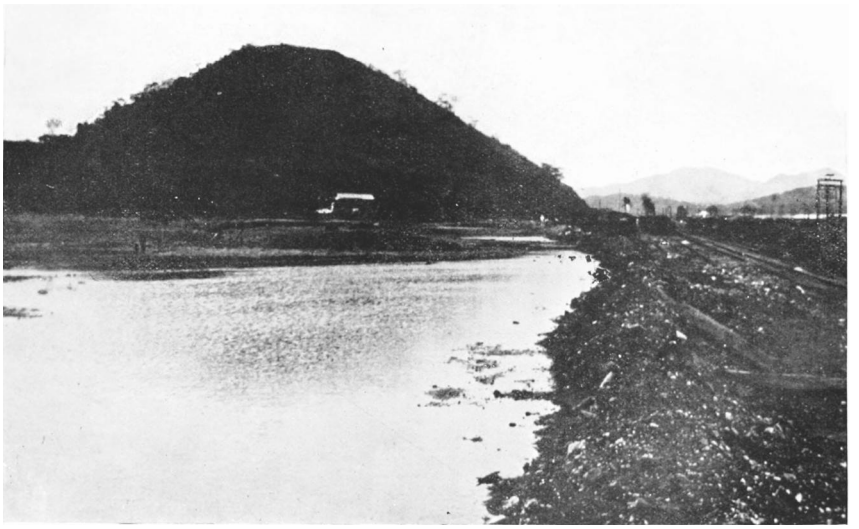


Figure 10.3 The "hydraulic fill" at Balboa. The future site of the official quarters of the Port of Balboa, at the Pacific end of the Canal. Originally a mangrove swamp, the ground level is being raised by pumping liquid mud onto it. The large pipe discharging the mud is seen in the middle of the swamp. The hill in the background is Sosa Hill. On the right of the railway the new docks are being constructed, and it is from them the mud is being pumped to raise the site for the new port.

them to its nest. Later in the day I saw a tree completely stripped of its leaves, and the surrounding ground was covered with the ant tracks and burrows. It was some time later before I learned that this ant had been, strange as it may appear at first sight, largely responsible for the high death rate from yellow fever among the higher French officials. The explanation is, however, quite simple. To protect plants in their gardens from the ant, people had placed a "moat" round each shrub. The "moat" is a double collar, made of the same material as ordinary flowerpots, and filled with water; and a well-kept garden with these moats round every shrub is a very curious sight. The moat was, of course, an ideal breeding place for the *Stegomyia*; and the larger the garden the greater the number of breeding places. So it came about that the higher officials, who naturally had the finer and more carefully cultivated gardens as well as the most numerous rainwater tanks, lived where the yellow fever mosquito was most abundant.

Crossing the docks on one of the great gates, I was fortunate enough to see an emergency gate in position, with some of its girders down. Then we visited a swamp where the open drains were being sprayed. Some of the drains were not more than 6 inches deep. Taking a boat, we made our way down the east diversion to the French Canal, which we followed up towards the dam. Then we entered a large basin, which had been excavated by the suction dredgers in filling the great dam with its hydraulic watertight core. When we entered the basin we saw fish jumping, and as we drew towards the corner where we were to land, the fish were in shoals. Our objective was a breeding place, the formation of which had produced an enormous swarm of *Anopheles*

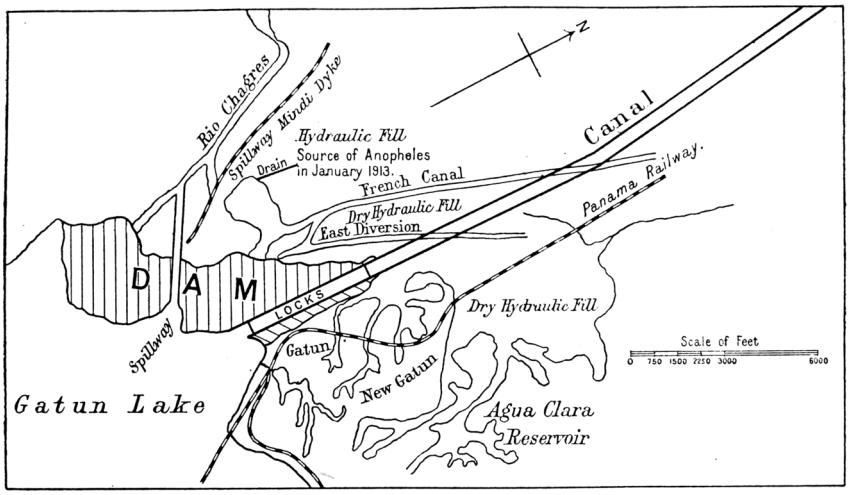


Figure 10.4 Sketch map of Gatun

Figure 10.5 Jungle trees killed by the "hydraulic fill" on the west bank of the French Canal at Gatun. From the swamp created by the fill enormous swarms of *Anopheles* flew to Gatun, which is over a mile from the swamp.

in Gatun town, which is a mile away. Some idea of the swarm will be obtained from the fact that the catch of *Anopheles* in houses rose from 149 in the week ending 26th October 1911, to 22,988 in the week ending 18th January 1912.

The swarm came from a swamp created by a suction dredger which, employed in deepening the Canal, had poured salt water and silt into an area of freshwater jungle.

The immediate effect of the salt water was to kill off the trees and all vegetation. The silt was deposited, and raised the land; while the salt water, more or less diluted from the fresh water in the jungle, ran off by a drain at the end of which we had landed. The dead and dying timber produced by this "hydraulicing" apparently provided abundant food for *Anopheles albimanus* (*A. tarsimaculatus*, a subspecies), and also for the fish, which swarmed at the end of the exit drain. I have never seen a greater number of fish together. They varied in size from 3 feet long to tiny sprats. They jumped, and splashed, and dashed up the drain, only to be driven back by its strong current. In every eddy and corner there was a black mass of the smaller fish. A number of tortoises were also seen on the banks, and some in the water. Evidently the end of the drain was a splendid feeding ground.

Walking up it for about 300 yards, with beautiful fresh green jungle on our left, we suddenly came to a drain across our course, on the other side of which the trees were dead and leafless—a picture of desolation. *Anopheles* larvae were easily found in the brown dead grass at the side of the lateral drains, although I was told they were not nearly so numerous as they had been. I was struck with the number of small fish in the water, and at one place where the lateral drain narrowed to a passage of about a foot wide and 2 inches deep, I estimated the fish were passing at the rate of four or five a second. Yet within a yard of this constriction we got from three to twelve *Anopheles* larvae at each dip among the dead grass. There was practically no current in these lateral drains. The protection afforded by the grass did not seem sufficient to prevent fish with any enterprise securing the larvae had they been so inclined. Many of the fish were as small as the "millions."

Farther on we stopped in some rather small open secondary jungle, but were not attacked by *Anopheles*. A few months before they had been swarming here, and in hundreds attacked people. Then we passed into an open space in which were holes produced by the blasting of tree stumps, in the preparation of the ground for the suction dredgers. *Anopheles* larvae were abundant in the green algae of these pools. Leaving this we struck through some small jungle, wading in the mud over the boots; and here Major Noble was attacked by an *A. albimanus*. Then we got on to the rather sandy bank of the French Canal (sandy because it had come from dredging the old canal), and made our way towards the place where the dredgers in the American Canal were discharging their silt. Here the mud and salt water were so concentrated that there was no food for larvae, and none were found. Crossing the French Canal, we landed on its east bank, and saw what had been an hydraulic fill. It was an excellent piece of land, with just sufficient sand in the mixture to prevent the sun-cracks which occur when pure mud dries.

Returning to Gatun, we visited a Y.M.C.A. After a much-needed wash, we dried ourselves with a "sanitary towel," which consisted of a tough blotting-paper torn from a roll. Then we went to the "hotel" which belongs to the Canal authorities, where we had lunch, consisting of soup, steak pie, and the inevitable ice cream. The lunch was served in excellent condition, although we arrived at two o'clock, the end of the meal

Figure 10.6 Land raised by hydraulic filling on the east bank of the French Canal at Gatun. The remains of the swamp trees are still to be seen.

hour. On the table was a pink-coloured quinine mixture, containing 5 grains of quinine to the ounce of water. It also contained a little alcohol.

After lunch we visited a ravine in which pipes were being relaid, because they had ceased to act properly. This was due partly to the roots of a certain coarse grass having gained entrance, and partly to the kind of stone that had been placed on them. These pipes had been down six years, and had been covered with stone from the Culebra Cut. This, as we have seen, is compressed volcanic ash, which weathers quickly, in fact becomes almost liquid when in contact with water, and when dried again forms an impervious black layer. It had acted, indeed, like cement, and had sealed the subsoil pipes so that water could not enter them. Even the soil here becomes almost impervious to water. So now a different stone is placed around the pipes and over them until above ground level. *No earth is placed over them, nor is grass allowed to grow over them.* At places I saw pipes only about 18 inches below the ground, and some of the lateral drains were not 6 inches below the surface. This appears to me too superficial, and perhaps is from a wish to economise in stone. If deeper, it seemed to me they would not silt so easily; but, as I learned later, this fear is unfounded; nor would grass roots enter so easily.

But I am chary of dogmatising, for the local conditions are evidently very different from what we have in the Federated Malay States. I was struck with this within the first hour I was at Ancon. For on my way up to the Administration building the path crosses a ravine in the bottom of which there was an open drain very similar to that shown in Figure 11.2, from the "Drainage at Kuala Lumpur." In Kuala Lumpur this form of drain was found suitable only where the grade was less than 1 percent; for at a higher grade the storm-water tore away the friable sandy soil from its sides, and the drain soon stood

isolated in the air with the water flowing outside. In Ancon, however, with a grade of fully 15 percent, the drain was in perfect order with the grass growing on each side and the soil undisturbed. The difference was due to the red volcanic soil (locally known as gumbo) being very adhesive when wet, and not liable to scour like the light sandy soil in the ravines of the Federated Malay States.

There is practically no sand in the Canal zone; that required for concrete is brought in lighters from various parts of the coast. It was the same adhesive volcanic soil that I had seen in Sumatra and in Hawaii. From this peculiarity in the soil a very cheap form of drain has been found practicable. It had been first employed by one of the inspectors. The place to be treated is drained in the usual way; then a length of chicken wire is placed in it, and covered with a mixture of sand, gravel, and cement. Here and there, especially at bends, the drain is "keyed" into the sides. This form of drain has the advantage of permanency and cheapness, for in many places it can be put down for 5 cents a foot, which is much less than the cost of subsoil piping. At the first place in Gatun where I saw the drain, the fall had not been utilised, and the drain was not running well; but further on in New Gatun I saw a good example of it in the bottom of a ravine that in times of storm must carry a great volume of water. In the ravine there was a ditch about 6 feet wide at the top, and 4 feet deep. In the bottom, which was 2 feet wide, there was a shallow "wire" drain, just sufficient to carry the ordinary flow of water. In a storm there must be at least 4 feet of water tearing down the ravine; yet the drain was in perfect condition, and the banks showed no signs of erosion.

Walking along the railway, we saw an old French locomotive boiler doing duty as a Sanitary Department oil tank. It is filled from a train that carries oil especially for such tanks.

In New Gatun—the native (or negro) quarter of this station—the houses are not screened. They have been built by private individuals; and as the rents are high, they are good investments, so I am told. The houses are divided into single rooms. Each tenement must, by law, have a sink, a water-closet, and a bath, connected with the sewage system, and properly trapped. The standard of cleanliness was no higher than I expected, but the water-closet is a clearly marked improvement on any possible system of dry conservancy, even for the negro. Cooking is done in a little box suspended over the verandah. All houses must have the proper number of dustbins, which are supplied and emptied by the Quartermaster's Department on behalf of, and at the expense of, the Sanitary Department. To prevent rat-breeding, the floor of the house must be cement, unless raised on an average of 3 feet from the ground. The walls must be of a single plank; or if double, the space in the lower foot must be filled with cement. Double walls, ceilings, and everything that provides hiding and breeding places for rats are discouraged.

Leaving the houses and the ravine with the wire drain previously described, we reached one of the filter stations of the Colon water supply. The water is heavily charged with vegetable organic matter, and alum is used to precipitate some of this. Four sand filters are housed in quite a small building. Attached is a small laboratory, where bacteriological and chemical analysis of the water is carried out. The filters have to be

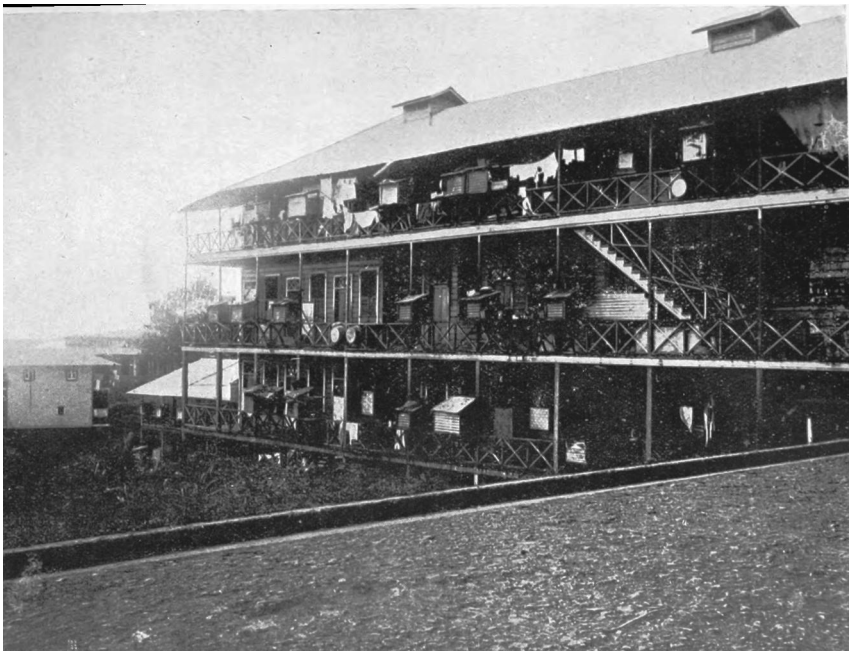


Figure 10.7 Unscreened native tenements at New Gatun. The houses are let as single rooms, and the "kitchen" of each house is the box seen hung over the verandah.

washed every fifteen hours, on account of the heavy silt, even after the precipitation. The bacteriological analyses were not very satisfactory at the time of my visit, the reduction of bacteria being only from 1000 to 250. This is probably due to no water being run to waste after the washing.

From the filter-beds we went up a ravine in which the water ran in a channel cut in a soft yellow sandstone composed of very fine sand particles embedded in a mud matrix. This small outcrop is evidently the origin of the sand seen in the swamp. The stone was soft enough to be cut with a pick. In many places small lateral channels had been cut, connecting springs on the earth sides of the ravine with the main channel. At places the stone was bare for 10 or 15 feet in a slope up the side of the ravine, and down this, small channels were cut for water oozing out at the top of the slope. In all the small channels, a piece of waste soaked in oil was anchored. Potholes innumerable had been filled up with stone and cemented over. We followed up this ravine for a considerable distance, and I must express my admiration for the excellence of the work and the intelligence and thoroughness with which it had been done.

Originally these ravines had been filled to a depth of nearly 10 feet with broken-down vegetable matter; and it was only when this had been cleared out that the inspector had come to the sandstone. Even then the channel was very irregular, and a good deal of work was required to convert the water-worn channel seen in Figure 10.8B into the excellent result seen in panel A of the same figure.

Figure 10.8 Ravines at Gatun, before and after drainage. A: an open drain has been cut in the soft sandstone of this ravine. B: a branch of the same ravine which has not been dealt with by the Sanitary Department.

Gatun has a permanent system of drainage unlike most other stations; for it has never been used as a "dump." It will always be important, too, as the site of three locks. The excellence and thoroughness of the work did not, however, depend on these circumstances; for at every station, whether permanent or temporary, whether the conditions were favourable to or difficult for the inspector, I saw the same intelligent care in the sanitation. Men evidently worked with brains on the Canal zone.

10.2.1 A Sanitary Inspector's Office. Returning to Gatun, we visited the sanitary inspector's office. Prominently on the wall was a chart showing the weekly malaria rate for the station for the past three years. It was one of the duties of the inspector to keep this chart up to date, so that the health of the station can be seen at a glance. In addition, he has plans of the whole station, showing the drainage systems and the grass-cutting plots. Every drain and its lateral of each system is marked in a uniform way. The systems are A, B, C, D, and E. The lateral drains are 2, 4, 6, 8; the even numbers on the right hand going up; and 1, 3, 5, 7, etc., the odd numbers on the left. In a table on the plan is shown the kind of ditch, and the [length of the ditch in] number of feet.

The plan of the grass plots gives the area of each plot. The work of cutting grass is no longer done by the Sanitary Department, but by the Quartermaster's Department on requisition by the sanitary inspector, who sends in his requisitions on Monday mornings, stating the number of plots, the number of square yards, the estimated cost, and whether to be done by horse-mower or scythe-men. The cost of the work is charged to the Sanitary Department.

Figure 10.9 A ditch at Miraflores Station. The grass has been cleared by burning. Ultimately, this will form part of the Miraflores Lake.

10.3 Miraflores

Monday, 19th May. By the 6.50 train to Miraflores, where I was met by Mr Shrimpton, the sanitary inspector. Near to his office we saw a well-burnt ditch. Oil is sprayed among the grass roots on the side of the ditch, and burned at the same time. The grass is almost killed, while on the surface of the ground a deposit of heavy asphalt takes place, which delays the reappearance of the vegetation. Although it does not entirely kill out the grass, it is certainly very effective in checking its growth. On some ditches asphalt was so thick that the side looked like an asphalt path. This can have required treatment only once in six months, and represented a great saving in grass-cutting.

Walking over what will soon be the bottom of the Miraflores Lake, we saw men clearing away jungle and scrub at contour level 55. This is to prevent much dead timber being formed when the lake is filled; for such timber forms a breeding ground for *Anopheles*. If the edges of the lake are free from timber, wave action will be sufficient to prevent *Anopheles* breeding along the shores, and the danger of ships becoming infected with malaria during their passage through the canal will thus be greatly diminished.

Ascending the dry bed of the Cocoli River, which had been dammed and diverted to form a temporary and auxiliary water supply for Panama City, we came to some rock pools. Numerous *Culex* larvae were present in some of them. The pools had been oiled some days before, and the larvae were young. The inspector had found *Anopheles* larvae in them about a week before, but we found none at the time of my visit. Climbing over the spill way, we examined the side of the reservoir without finding anything. When it had been first filled, it had supplied a swarm of *Anopheles*almost as great as that at Gatun. It was not intended originally to use this as a drinking supply, and so the vegetation had not been cleared away; indeed some small dead trees were still standing. The dead timber had supplied the necessary food, and Miraflores was inundated with the insects. As many as 11,343 had been caught in a week. In the week prior to my visit five men had caught 354 *Anopheles*in seventeen houses and six cars.

Coming back by the lock, we found a few small larvae in a trickle of water overgrown by grass. Then we visited a large swamp partly natural, but mainly caused by the engineers having held up the waters of the Rio Grande for a fortnight. They required the water to fill a portion of the Canal before they could blow up the dam that kept out the Pacific Ocean. In Mr Bishop's book a very good photograph of the explosion is shown; 16 tons of dynamite were let off at one charge.

In the swamp we found no larvae. An oil-boat is used on this swamp; for it is the only means of reaching many of the grassy patches where larvae are found at times. Crossing the line we reached the East Miraflores "dump." It looked about 20 feet high, and was half a mile square in area. The surface was dry, but from the bottom layers water poured out. Heavy rain had washed a good deal of the soil from the dump into the ditch cut along it, and the drainage channel was completely obliterated. As a consequence there was a swampy patch in which we found *Anopheles* larvae.

Making our way through some scrub, we came to a small clear stream, which we followed up for some distance, without, however, finding larvae. In the pools were many small fish; but there was plenty of cover for larvae, certainly as much as in the swamp at Gatun. This stream is outside of the area under routine treatment. Returning to the railway station, we then struck up the Camatillo River, ultimately to be a branch of the Miraflores Lake, and followed a small subsidiary stream to its source, where among the grass we found a few *Anopheles* larvae. Our way back was along the Camatillo, which, having been partly dammed by the new wagon road from Panama to Gorgona, had created an extensive swamp. It had been thoroughly oiled, and was free from larvae. At this point (see Figure 10.10) I met a negro with a bottleful of large *Anopheles*larvae, which he had collected for Dr Darling from beyond the oiled area.

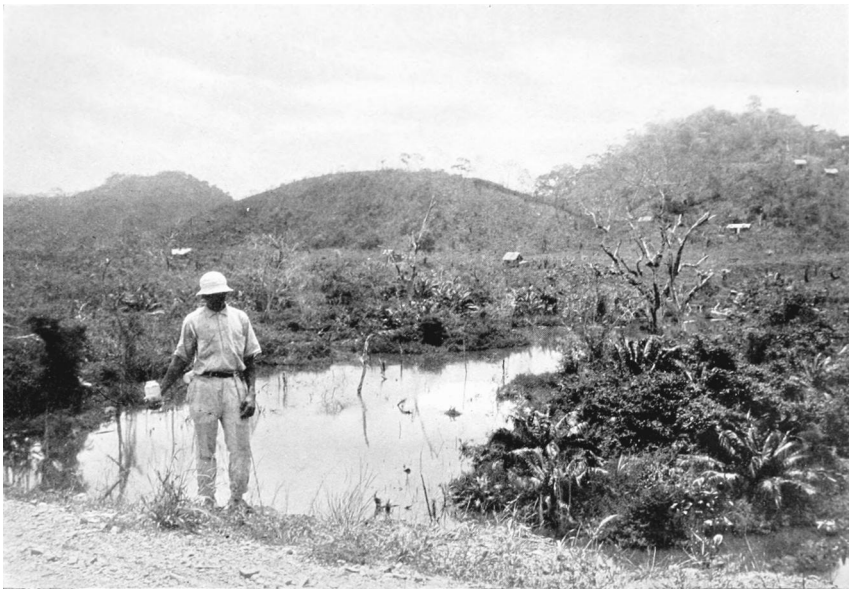


Figure 10.10 Swamp above the waggon road at Miraflores. The negro has a bottle of *Anopheles* larvae. Several "shacks," or huts, can be seen scattered about in the bush.

At Miraflores the sprayers use the following mixture: larvicide; 1 gallon; water, 3 gallons; crude oil, 8 gallons. The oil is added last. Mr Shrimpton considers the addition of water an improvement on a mixture of only the larvicide and crude oil. In a month in this station they use from 4000 to 9000 gallons of crude oil, and from 1000 to 2000 gallons of larvicide; the amount depends on the season and the area to be oiled. The area may be greatly extended when for some special purpose the engineers dam up a river or stream. At the time of my visit, many acres of swamp had been created by the damming of the Rio Grande, and this required a large additional expenditure on oil.

10.4 Gorgona

Tuesday, 20th May 1913. By the 6.50 train to Gorgona with Mr Bath, divisional inspector. At the station we were met by Mr Park, the sanitary inspector, who took us to the condensing station. At many of the stations on the Canal condensed water in bottles is delivered to the houses by hand, while raw water is supplied through the pipes. This is more economical than putting down filter plants for stations which will be abandoned ultimately. Gorgona will soon have to be abandoned, because it will be covered by the waters of Lake Gatun.

At the reservoir we found coolies cutting the grass that grew between the stones facing the dam; and in some grass debris we found *Anopheles* larvae. The water in the reservoir was low at this time, and ground usually submerged was covered by a yellow thallus about one inch high. In this no larvae were found; nor were they ever found in it, so Mr Bath told me, because no dead vegetable matter is found here. Nor is long grass per se dangerous; but it may become dangerous if it retains debris to which fish cannot

gain access. Larvae are almost certainly found when fine pieces of wood have been in water long enough to become covered by a fine "furry growth." This growth seems to be both a food and a cover for larvae.

Paddling across the lake, we came to a stream which came down from the jungle, but which before entering the lake had lost itself in a bank of sand. Cut off from the lake, and imprisoned in the stream, were thousands of little fish about twice the size of "millions." A few were dead, and the remainder were reduced to a minimum of water, and in great danger of death. They formed almost a solid mass. Following up the stream we found a few larvae in shady side-pools, especially among some masses of whitish roots. They bred out as *A. malefactor*, a mosquito which does not carry malaria. Mr Bath told me before we went there he did not expect to get *A. albimanus*. Returning to the lake, we went to another and larger stream with a considerable current. It was full of grass, and in Malaya I would have expected *A. albirostris*, but no larvae were found, and Mr Bath told me *A. albimanus* could not live in such a stream. Clearly *A. albimanus* is not a stream-breeder like *A. maculatus*, or even like *A. albirostris*.

Then to another stream where the current was almost absent in the wider portions of the channel. Algae had grown here, so the inspector told us; but he had drawn 5 lbs. of copper sulphate in a bag a few times up and down the stream, and destroyed them, so no larvae were found. Copper sulphate is used in the reservoirs whenever algae threaten to grow. I was not surprised to hear, a few days later, that Mr Bath had returned to the reservoir and lifted the imprisoned fish back into it; nor that, improvising a sifter with his handkerchief, he had removed all debris left by the grass-cutters we met on the dam, and every larva with it. To some this may appear meticulous care; yet it is just this thoroughness which has made the construction of the Canal possible. Mosquitoes may be small, but they are formidable opponents, ever ready to find the weak spot in the human attack or defence. Those who know this enemy best are the most wary; while many a fine champion has bitten the dust by neglect of small and apparently unimportant precautions.

Half a mile from the town are the slaughterhouses, and beyond these were deep shady pools, the home of *A. malefactor*. With the rising of the lake water these pools have become very extensive; and although Mr Bath expected to find some larvae, none were captured, because recently the area oiled had been extended to these pools, and the oiling had been thoroughly done. When coming back I noted that, as in other stations, the houses in the native quarter were not screened. Near to the railway depot we saw the Sanitary Department oil tanks, which are connected with the trans-isthmian 8-inch main [oil pipeline]. The photographs of the man with oil-sprayers, and of sprayers at work on ditches in a swamp (see Figure 10.11), were taken here. The stream and side ditches were as black as pitch after the oil had been applied.

The following table gives the number of mosquitoes caught at Gorgona in the preceding four weeks:

A

B

Figure 10.11 Oil sprayers at work. A: One of the men belonging to the Sanitary Department with a knapsack oil-spraying machine. B: Two men spraying oil on a swamp at Gorgona. The notice board says, "no hay pastes," which means that the grazing of cattle is prohibited. "Clean weeding" is not attempted.

Table 10.1 Insect vectors caught at Gorgona during four consecutive weeks in April/May 1913

Anopheles	37	37	20	41
Culex	91	94	188	345
Stegomyia	35	0	0	0

10.5 Matachin

After lunch at the hotel we walked to Matachin, the next station to Gorgona, on the way finding a few *Anopheles* larvae, but no pupae, in a recent pool in a railway cutting. Larvae are often found in pools five or six days after oiling; but they never pass beyond the larval stage, for they are killed by the next oiling. The Manual says: "The finding of pupae in a sanitary district will be considered as neglect on the part of the Inspector." In a climate with such a heavy rainfall, in a country covered with vegetation so dense, and in a place where the surface is so liable to be altered by the engineers, it shows an extraordinary degree of thoroughness that such a rule could be made. During my visit I examined pools for mosquitoes in every part of the zone, and I can bear witness to the fact, that although larvae were, as I record, occasionally found, on no occasion did I find pupae within a sanitary area.

Between Gorgona and Matachin we passed many earth-drains, all properly oiled. Just above Matachin railway station there is an extensive swamp, caused by the collapse of a culvert under the railway. At the time of my visit the culvert was completely blocked, and men were digging at the lower end of the culvert to clear it; and the water level in the swamp was rising rapidly on account of the rains. From time to time the water bursts through the culvert. I was struck by a remark made by the inspector here, on the difference this made in the breeding places in the swamp. The remark was made quite casually, but it was evidence of the care with which the subject had been studied that, to this inspector, his remark should be a commonplace.

The swamp was being oiled from a punt. On the lower side of the railway there was another extensive swamp, again due to interference with drainage by a "dump." The box culvert had collapsed and an overflow had been cut, but it was too high for proper drainage. This station will be abandoned shortly, as both it and Gorgona will be covered by the waters of the Gatun Lake; in the meantime these extensive swamps, which could easily have been drained, require a heavy expenditure of oil.

During my visit to Panama I was never able to satisfy myself that from a distance I could recognise the smaller swamps and damp places by the vegetation alone, as I can in England and the Federated Malay States. In these countries patches of dark rushes and sedges, lighter or darker green, or bluish tinted grasses, mark out the wet ground of a swamp, or of a spring on a hillside, as if with a flag. In Panama there was nothing so distinctive, as far as I could see. One extensive swamp, near to Panama City, was so evenly covered by bright green rushes, that it looked like a rice field; and Major Noble pointed out a plant, whose name I have forgotten, as usually found where the ground is wet. It is known in Malay as "brakas," and its leaves are used to shade young coffee

plants. It often grows in brackish swamps. Beyond these there was nothing distinctive in Panama.

In Panama the ground is covered mainly by three species of grass (in a non-botanical sense). The most widely spread is what is known as "cabaloté." It is probably not a true grass. It is very prolific, has a coarse flat stem, breaks easily at the joints, from which it throws out roots, and has a thick fanlike head. It grows to a height of 4 or 5 feet in favourable places, such as this swamp at Matachin; but it also grows freely on dry soil. It is useless as fodder, and is the grass which finds its way into and blocks subsoil pipes; I have seen nothing like it in the Federated Malay States. I was warned there were deep holes in this swamp, and the inspector fell into one in crossing; but from the vegetation there was no guide to what was swamp and what was solid ground.

Para grass (*Paniceum muticum*), on the other hand, is an excellent fodder. In appearance it is much like Guinea grass, but it does not grow in clumps like the latter. Para grass is very abundant on the zone; Guinea grass, though common, is much less so. Bermuda grass is a short fine grass, excellent for lawns. It is imported, and is planted on the savannas for cattle-grazing. In the Federated Malay States the coarse grass lalang, which displaces practically all other vegetation in open spaces, dies out when constantly mown, and is replaced by some of the short surface-feeding grasses. But in Panama nothing analogous to this takes place, and the scythemen have always to contend with these strong, coarse grasses. It would perhaps be an advantage to Panama if some of our short grasses were introduced: the cost of the upkeep of the grass areas would perhaps be reduced.

On the following day (21st) we (Mr Bath and myself) returned to Matachin and took a boat on the Chagres River. As the Gatun Lake was now being filled, the river was much above its original level, and was continually rising. It had consequently flooded what had been dry land, covered with grass. Mr Bath had visited a stretch of the river opposite Matachin a few days previously, without finding larvae in the grassy banks. Despite a careful search, we only found one small *Anopheles* larva in the grass. But in driftwood in an eddy farther up, we found a considerable number of larvae, showing again the predilection of *A. albimanus* for dead wood. While paddling along, Mr Bath showed me what he called "seaweed" grass. It consists of a long stem, from every few inches of which radiating rays break out. When crushed in the hand, it has a strong garlic-like odour. He told me that he had never found larvae where this existed.

Landing on the Gambon dyke, which keeps the Chagres from flooding the Cut, we dropped into the Cut and walked along it for about a mile. In the centre of the Cut is a 20-feet wide drain, which keeps the bottom fairly dry, but in many places there are breeding pools, all of which are oiled weekly. To facilitate this, oil pipes have been carried to the bottom of the Cut at certain places. In places the bottom of the Canal is like a mosaic of stones loosely set, between which are little pools of water. These are prolific breeding places for *Anopheles*, and not the least important part of the inspector's work is supervision of these countless isolated small pools. At the sides of the Cut, innumerable small springs exude, each of which must also be oiled. When we consider that this Cut is 9 miles long, that at the south end the sides are terraced to a height of 400 feet, and are

Figure 10.12 The Chagres River. Anopheles found among the driftwood in the eddy at the place where Mr Bath is seen the photograph. Along the rest of the river bank no larvae could be found.

constantly being altered in the excavations, some idea will be gained of the magnitude of the sanitary work done. The Cut is a special danger; for a series of stations containing thousands of people have been built on its banks, well within the range of mosquitoes breeding in it.

Climbing out of the Cut at Haut Obispo, we walked to Bas Obispo, past Camp Elliot, and had tiffin at the hotel. Through Bas Obispo runs the Rio Mandingo, which, with its tributary the Camacho (both more or less artificial now), drains the land on the west of the Canal into the Gatun Lake; it is a stream about 20 feet wide. At the time of my visit, the rains swelled it occasionally to many feet (6 to 10) above its ordinary level, and washed all larvae away. It was, therefore, not oiled at the time, nor were its larger tributaries. But while in wet weather there is this saving of oil, more oil is required for

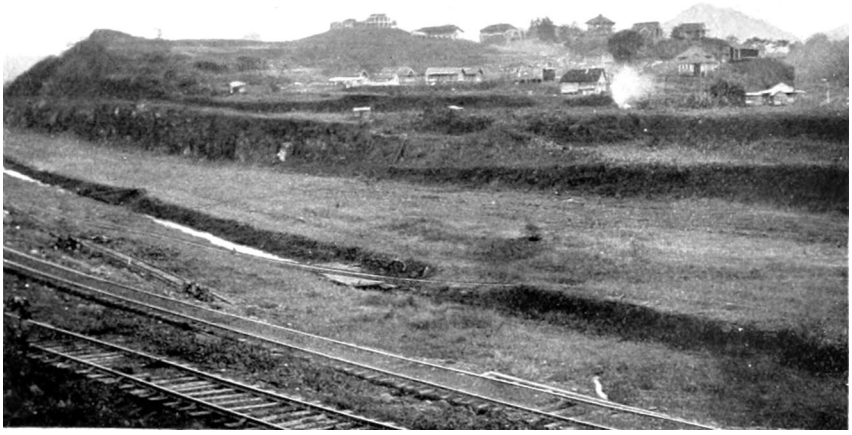


Figure 10.13 The north end of the Culebra Cut; looking towards Bas Obispro. In the centre of the Canal is seen the drainage ditch which gathers the water in the Cut to a pumping station on the side of the Chagres River. By this means the Cut is kept dry.

Figure 10.14 The Rio Mandingo at Bas Obispo. This is not oiled except in very dry weather.

pools and springs which appear elsewhere; so that what is saved in one direction is lost in another. To put it another way, *A. albimanus* flits from one kind of pool to another according to the season. In dry weather it lives in pools in stream beds, and makes its way on to high ground. But in wet weather it is washed out of these, and lives in pools formed in low swampy ground, and in the springs formed on hillsides by the rain. All this is known in Panama, and the sanitary inspectors alter their tactics accordingly.

After tiffin at the hotel, where I asked for, but could not obtain, quinine, we took train to the next station, Las Cascadas; and I was interested to see that in the town they had the combination of a pipe drain below an open cement drain, which we have used at Port Swettenham, and which seems to me to have so many advantages for towns. In the ravine behind the houses we saw a tile drain covered by stones. At one place it was evidently blocked, for the water was welling out, only, however, to disappear within the next 10 feet. Lower down this ravine, where the drain was open, there were several side streams, all of which have small barrels dripping oil. One barrel in particular attracted my attention, or rather the cutting away of the scrub attracted my attention to the barrel. It was about 20 feet from the ditch, and about 10 feet above it. Only a careful examination of the bank of the ditch could have led to the detection of this spring, and it was another indication of the "brains" used in doing the sanitary work.

From Las Cascadas we walked a couple of miles to Empire, passing Camp Otis on the way. The whole length between the two stations was oiled. In passing we visited a field where formerly, in cattle hoofmarks, *Anopheles* had been found; but the marks of the cattle did not contain water at the time of my visit. There we met what looked like a water cart, with a long pipe projecting out on one side. It sprinkled oil in the roadside ditches, not water on the road, and was the invention of Mr Trask, one of the inspectors. The flow of oil is controlled by a valve at the driver's hand, and the pipe can be raised or lowered by a foot-pedal.

10.6 Empire

As we entered "Empire" we met a *Stegomyia* gang. "*Stegomyia* Day" is held once a week, and the gang then visit every house. I saw two large collections of old bottles and tins, etc., on the side of the road, awaiting removal. All these years of sanitation had quite failed to overcome the tendency of the negro to throw rubbish out of his house. Prosecutions are instituted only if the offender is caught in the act. If the presence of bottles and tins on a man's premises were an offence, then most of that negro population would have been in court. Each of the men belonging to the gang was armed with a sharp-pointed iron rod about 3 feet long, with which he transfixed and lifted tins, or smashed bottles. Some inspectors insist on bottles being lifted, not smashed; because even when broken the bottom pieces may remain intact and constitute a danger. I confess I was rather struck by this scene. Here was anything but the military despotism and tyranny which I had heard of before coming to the zone; but it was quite in the spirit of all I had seen and heard of it.

The *Stegomyia* is prohibited on the zone. The Manual says: "There must be no *Aedes (Stegomyia) calopus* breeding in the Canal zone." Yet the inspectors had told

Figure 10.15 Oil cart designed to spray oil on the roadside ditches. This oil is controlled by a valve at the driver's hand. The pipe can be raised or made lower by a foot-pedal.

me they only emptied tins or barrels, etc., containing rainwater. They did not smash them, because they found it made enemies of the people, and made their work more difficult. From what I saw in the zone, I am satisfied that the sanitary inspectors act in the spirit of the rule of their Manual already quoted (see Section 9.3.2) and realise that "the advancement of sanitation is a matter of education rather than force." The following rule states: "The aid of the police and judiciary should be invoked when ever necessary, but only—except in emergencies—after due warning has been given in writing, on the prescribed form. …"

I gathered, however, that the inspectors rarely went to court; and in 1912 the Annual Report for the Canal zone records 2671 notices, 200 arrests (i.e. summonses) for violation of sanitary regulations, and 181 convictions. Surely very small numbers, when we consider that the area is 50 square miles, that the population of 79,279 is composed mainly of negroes, and that on the zone the standard of sanitation is higher than is to be found elsewhere in the tropics, or, indeed, in most places out of the tropics. This is a complete answer, in my opinion, to the statements that sanitation in Panama is the result of putting inhabitants under military discipline.

The glee with which the following story was told me indicated, too, that the magistrates on the zone were, like most other magistrates, rather on the side of the accused than of the sanitary inspector. A negro baker had been charged with being drunk, and keeping his premises in a dirty condition. The magistrate held the charge not proven. The sanitary inspector asked if he might in the presence of the magistrate warn the prisoner to keep his place cleaner, to which the magistrate agreed; and the inspector began: "Now, Mr Sambo, I want to warn you that the next time you get drunk, and fall asleep with your dirty boots on the dough, I will run you in." As the magistrate

bought his bread from this baker, the inspector hoped he had given both prisoner and magistrate a warning.

Whether the story is apocryphal or not, I cannot say, but I took it as showing that the sanitary inspectors did not hold the magistrates in the hollow of their hands; and certainly there is no military discipline in Panama that I had heard of. The sanitarian in Panama, as elsewhere, had found the work was done quickest, most satisfactorily, and with least friction, when done by himself; and the less he asked people to do for themselves, the better. For the sanitarian this is the beginning of wisdom. The fact of the matter is, that the sanitarians in Panama are men of common sense and have a sound knowledge of human nature. They know that while a few men may be born poets, none are born sanitarians; and that the ordinary man finds sufficient employment for his time and thoughts in the ordinary struggle for existence, without having to bother about sanitation. And so, when the Department of Sanitation wants anything done, it does it for itself.

Empire is one of the best laid out stations on the zone. The houses are built on the gentle slopes of the hills. There are wide areas (463 acres) under grass, cut by a horse-mower; and there is a good permanent drainage system. Between the official quarter and New Empire, the negro section, runs a stream from the Camacho Lake, about 3 feet wide and 6 inches deep. It is not oiled, as the water has to be sterilised for drinking. Instead of oiling, the banks are “trained;” and this is found sufficient to prevent larvae from appearing. The “training" is done once a year, after the rains, and consists in taking the stones from the stream and placing them along the banks. During heavy rains they are displaced, so “training” is not done until the dry season has definitely set in. In wet weather the stream is harmless.

10.7 Culebra

This station I did not visit until the the 28th; but as it adjoins Empire, I may as well describe it now. The Commission houses are on hills between the railway and the Cut. To the west of the railway there was formerly a swamp, but it has now been filled. All the filling had not been done at one time; and as the filling on each occasion had interfered with drainage, several systems of drainage had disappeared. Figure 10.16 shows the extent of the filling, and also how the filling has obstructed a stream.

On the side of this filling opposite to the Commission quarters is the native quarter entitled “Golden Green.” The houses are on the slope of a hill, the foot of which is carefully drained and oiled. This quarter is not connected with the sewage system, and there are a number of pit-closets about. There is also a “range closet,” in this instance a large cement tank from which the sewage is pumped. The odour from it is very offensive, and showed its great inferiority to the trough closets. It struck me as a “spot,” and one of the very few, in the Panama sun. There is a pipe water-supply.

At Washington I heard Colonel Gorgas tell his audience that there is one drawback to abolishing mosquitoes from a place, and it is that when one or two gain entrance into a house, the Sanitary Department receives a letter from an indignant household, to the effect that two mosquitoes had been seen, and that one had bitten him. I was

A

B

Figure 10.16 The swamp at Culebra. A: The photograph shows to what depth the swamp at Culebra has been filled. B: The photograph shows how the "filling" at Culebra has completely blocked one of the streams draining into the swamp seen in the upper photograph.

not a little amused, therefore, when Mr Shropshire, the sanitary inspector with me, was stopped by a lady, who said she was so glad that she had met him, as she was just going to write to say her little girl, when playing below the house, had seen seven mosquitoes. Need I say Mr Shropshire politely intimated that the matter would receive immediate attention.

Yet this scene took place in a station where the conditions were specially favourable to the mosquito. To the east was the deepest portion of the Cut, which was here terraced to a height of 400 feet, with each terrace a mass of springs capable of breeding mosquitoes. Here, too, slides of thousands of tons of soil were constantly creating new pools, and all required increasing attention. That such a complaint as the above could be made, that such a scene was possible, is a proof of the thoroughness with which the anti-mosquito work had been carried out.

At Ancon my experience was the same. During my stay of nearly three weeks, I saw one mosquito in my room, and five outside. One evening after rain I sat outside in the garden, but no mosquito attacked me during the five minutes I was there. I certainly was not bitten by a mosquito when in Panama, except when in the bush beyond the sanitary areas.

I was told the tile drains were not running very satisfactorily at Culebra, for the same reasons as in Gatun, and that some were being replaced by the chicken wire drains, and others were being relaid.

10.8 Pedro Miguel

Pedro Miguel lies at the south end of the Cut, and on the opposite bank from Culebra. I visited it on the 26th May, and was met by Mr Mitchell, the sanitary inspector. Crossing the locks we reached a lake, formed by the partial blockage of the Rio Grande. The lake is half a mile from the houses, yet it is considered necessary to oil it. On the sides of the lake are four large oil tanks belonging to the Sanitary Department. From these the oil-boat is supplied which sprays the grassy edges of the lake. The tanks are connected with the trans-isthmian oil main by a pipe; and they deliver oil into the boat also by a pipe seen in the photo, thus diminishing the handling of oil.

Returning to the locks, Mr Mitchell told me fifteen men were employed for two days in oiling them, and that water suitable for *Stegomyia* was constantly being found. Every piece of machinery and every portion of the construction had to be scrutinised; the most unexpected places often contained water, as an example of which I might mention the tops of the tall concrete pillars on which the iron lamp standards were to be placed.

The Commission quarters are on the slope of the hill, and command a fine view. The land below will ultimately be covered by the Miraflores Lake, so permanent drainage has been carried down only to the 55-foot contour-level, i.e. the future lake level. Below this the drainage is carried off in earth drains, and these require much more supervision than the upper concrete portions. Beyond the houses we descended into the valley of the Pedro Miguel, a stream about 20 feet wide, with an average depth of about 9 inches. The bottom is stony, the current fairly fast in places; but there are a fair number of backwaters, which in the Federated Malay States would certainly harbour *A. maculatus*.

A

B

Figure 10.17 Pedro Miguel—settlement and lake. A: Pedro Miguel from the south. The smoke of the incinerator is seen in the middle distance. The incinerator, some of the houses on the side of the hill, and the whole of the lower land will be submerged when the Miraflores Lake is filled on the completion of the Canal. B: Lake on the Rio Grande at Pedro Miguel. Oil tanks belonging to the Sanitary Department on the side of the lake supply the boat with oil. The boat is seen taking in oil from a pipe connected with the tanks. The edges of the lake are regularly oiled.

The stream is not considered a danger except after a rise or subsequent fall of the water level, when larvae may be found in side pools. There was a good deal of scrub on the river banks, and my impression was that it did not receive much attention from the Sanitary Department, and therefore could not be as dangerous as a similar stream in the Federated Malay States. This may be, however, because all the small lateral feeders have been carefully oiled. I sincerely hope that the elimination of the lateral breeding places in Malaya will remove the danger of our larger streams.

Re-crossing the stream, we visited the incinerator, a simple but effective structure, the smoke of which is in the middle distance in Figure 10.17A. At the sanitary inspector's office I was shown his system of working.

The district is divided into five parts, each of which is treated weekly. Saturday is called "Pick-up Day." No less than two days in each week are spent in oiling the locks. The men may have their routine broken into by various emergency duties, and "Pick-up Day" allows any interrupted work to be completed.

At the railway station I noticed a mosquito-proof signal box where the holes in the walls through which the wires passed were carefully closed with cloth. Nothing seems to be overlooked in this work, nothing too insignificant to receive attention.

10.9 Paraiso

On the 30th another spot in the sun—the electrically controlled clock in the hotel, being five minutes late, made me miss the train for Paraiso. *Absit omen.* However, after an eventful journey in a motor car, whose tyres seemed to have caught the explosive tone of the zone atmosphere, I arrived at my destination and found Major Noble. We then walked along the Cut to Paraiso, a town only the shadow of its former self, for most of it has disappeared into the Cut. Climbing down into the Cut, we walked along, examining the numerous springs which come from its sides until we came to the Cucaracha slide—one of the two longest on the Cut, and some 67 acres in extent. The oiling of this is very dangerous, as some of it is like a quicksand. In other places, as I saw when we reached the top later in the day, there are fissures and crevasses many feet deep. Two steam shovels working from north and south had met on the level of what is to be the bottom of the Cut, on the 20th May, but on the 26th, four days previous to my visit, the Cucaracha slide had moved forward and blocked it again. The photograph shows the new slide, and the shovels at work clearing it away. These slides are of interest, not only to the engineer but to the sanitarian, for a large slide may block the central drainage channel and create an extensive breeding area. Farther on I saw another slide, where the side of the Cut had sunk while the bottom had been heaved up and upset a steam shovel.

Opposite to the town of Culebra we climbed from one terrace to another out of the Cut, and had an excellent view of the terraces on the Culebra side of the Cut. On the way up I got a drink of iced water from an engine driver. Each engine and shovel is allowed 10 lbs. of ice each day, and part of the equipment of the engine is a vessel to contain water, which can be drawn off by a tap. Water is also provided for men on all the locks, and special supplies are sent to those working away from places where there

Figure 10.18 The Cucaracha slide on the right is seen blocking the Cut, which has been cut through to the bottom level a few days before. Above the slide is Gold Hill. The houses on the right edge of the Cut in the distance are at Culebra. At this point the Cut is nearly 500 feet deep, of which 300 feet have been excavated.

are water-taps. This prevents the men from drinking from pools or streams which may be polluted.

We returned to Paraiso by the waggon road which runs behind Golden Hill, on the way climbing up the hill to look down on the Cucaracha slide. From this point the best idea of the enormous size the Cut can be obtained. It looks like half a mile to the top of the opposite bank; what it actually is I do not know. Some idea, too, is obtained of the great mass of earth which has been moving at intervals from the time of the French. Great fissures and crevasses covered its surface, and I was quite glad we had not attempted to climb up its face, as had been our original intention.

10.10 Colon. Cristobal. Mount Hope

On 22nd May, with Mr Bath to Colon, where we were met by Dr Connor, who drove us to Mount Hope. Colon was built originally on a coral reef, and the town site has been made by filling. Between Colon and Mount Hope the road is just above the swamp, the original condition of which is still seen on the left.

The houses on the side of the road are built on piles; much like Malay houses, except that the piles are shorter, and the water at high tides runs under them. Although there is little scope for drainage, the swamp has a system of shallow drains, which to some extent concentrate the water and facilitate the oiling. Beyond the hill at Mount Hope we came to the edge of a deep swamp which extends from Mount Hope to Gatun. The

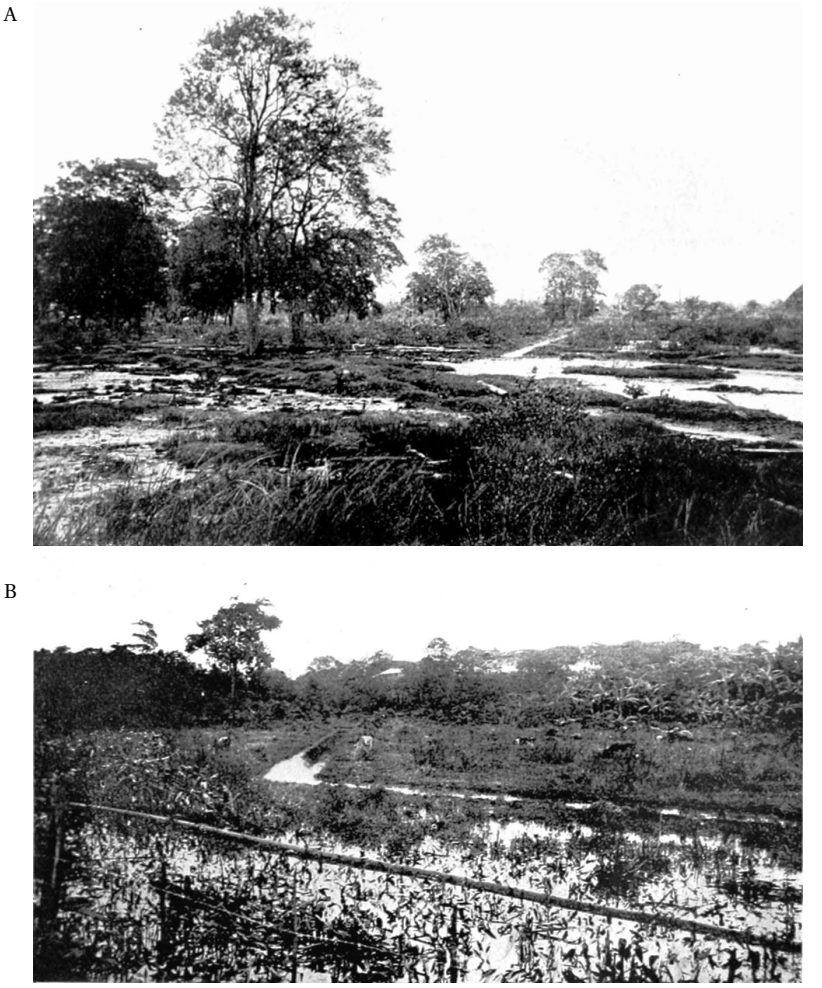


Figure 10.19 Swamps near Mount Hope. A: On the east side of the road from Colon to Mount Hope. The land is very swampy, being covered by all tides. The photo shows one of the shallow drains employed to drain this almost undrainable swamp. B: Looking towards Mount Hope, from the south-west. The very swampy nature of the land in wet weather is well shown in the photo.

engineers building the railway found great difficulty in getting the railway over it. No less does it present difficulty to the sanitarian; and the photographs in Figure 10.19 show how swampy the ground is in wet weather, despite the drainage.

This system of drainage was constructed only in 1912. Year by year the drainage work on the zone has proceeded, and the health improved. It was on the hill at Mount Hope that the United States troops were so severely attacked by malaria when the zone was first occupied, and in this village Colonel Gorgas found 100 percent of the children with enlarged spleen. After walking round the village and visiting the cemetery, with its mournful record of young lives destroyed by yellow fever, we went back to Colon. It

Figure 10.20 Colon Hospital. A back view, taken on a wet day. The front of the buildings project into the sea, as they are built on a thin coral reef.

presents little of interest to the sanitarian, who finds it difficult to realise that the clean, well laid out town was originally a filthy, miserable swamp.

A visit to Toro Point on the 27th, however, gave me some idea of what the original site of Colon was. Toro Point is on the opposite side of the bay, and work is being carried out there in connection with the breakwater, which runs out 2 miles into the sea, and with the fortifications. The launch landed us on a little jetty fixed on the coral reef. The houses are built on the sea-beach, which is composed of coral sand; and behind them is a mud swamp, similar to what is seen between Colon and Mount Hope. Through the swamp drains have been cut, and into these the tide comes every day; only at spring-tide does the sea cover the swamp entirely.

Beyond this salt-water swamp there are two extensive areas of freshwater swamp, about a quarter of a mile from the houses. These have been drained very thoroughly by a system of drains, which inter-communicate to prevent flooding should one of the outlets become blocked by shifting sand. About half a mile from the houses we came on a stream which we followed up for another half mile, when we came to the rock pools with *Anopheles* larvae. Some larvae were also found in backwaters; unfortunately they died, and I could not determine whether they were *malefactor* or *albimanus*. Larvae previously taken were, I understand, *albimanus*.

With swamps so extensive and so close to the houses, no one will be surprised to learn that when men were first stationed here, malaria had been severe. But the numbers in Table 10.2, which show how rapidly this was overcome, are indeed remarkable. In July and August 65.88 percent of the men were admitted to hospital, yet by the last week in the year the percentage was down to about 1/2 percent per week, and the total for the last five weeks was about 4.79 per cent. The measures which produced this result were screening, oiling, and mosquito catching. Drainage was completed later on.

Table 10.2 Percentages of the labour force in Toro Point admitted to hospital with malaria, per week, in 1910 and 1912

1910			1912		
Week of		%	Week of		%
July	2	9.16	July	6	.62
	9	6.83		13	1.23
	16	5.00		20	.62
	23	5.34		27	.86
	30	6.67	August	3	.62
August	6	10.32		10	.74
	13	6.86		17	.12
	20	8.96		24	.86
	27	6.74		31	.25
September	3	7.25	September	7	.44
	10	3.74		14	.44
	17	4.64		21	.29
	24	7.68		28	.29
October	1	7.28	October	5	.00
	8	4.57		12	.15
	15	2.41		19	.44
	22	2.71		26	.00
	29	1.77	November	2	.29
November	5	1.88		9	.59
	12	1.41		16	.15
	19	1.58		23	.15
	26	1.83		30	.29
December	3	1.26	December	7	.62
	10	1.21		14	.62
	17	.65		21	.00
	24	1.11		28	.00
	31	.56			

The corresponding period in 1912 is no less remarkable, and it is not without interest that from the 15th of January to the end of February, 1912, there was a great swarm of *Anopheles* in Toro Point, just as there was at Gatun at the same time. The two places, although on the same stretch of land, are fully 5 miles apart, and it was never actually determined whether the swarm originating in the hydraulic fill at Gatun had travelled through the jungle to Toro Point, or an independent breeding place had existed there. Mr Bath walked through the jungle from the one place to the other, finding the mosquitoes all the way; but he thinks it not impossible there were a series of breeding places, only some of which he found.

10.11 Corozal

This town is nicely situated on sloping ground, but contains nothing of special interest in its history except the appearance of a great swarm of *Anopheles* in May 1912. Below the town is a mangrove swamp, part of which had been shut off by an embankment. When the rains appeared this embanked area became partially flooded; but, whereas in Gatun salt water had been poured on freshwater jungle, in Corozal, fresh water (rain) was poured and remained on saltwater jungle (the mangrove swamp). The result in both cases was a mixture of salt and fresh water, and in both there was an enormous swarm of mosquitoes. I could not ascertain whether in this instance there was any special feeding for the *Anopheles*, but it is probable that the alteration of the composition of the water killed some of the vegetable inhabitants of the swamp, and so provided food for *A. albimanus*.

10.12 Frijoles

This station and Monte Lirio are small places on the new railway line, and their inhabitants came from villages now at the bottom of the Gatun Lake. On the 23rd May I visited Frijoles, and was shown round by Mr Smith, the sanitary inspector. The population consisted of about 150 souls, mostly negroes. There are a few Panamanians, and two white men, the station-master and the sanitary inspector. The latter is also in charge of Monte Lirio, a larger station. The people live in a few huts ("shacks," as they are called), and the railway employees in screened railway cars.

No oiling or draining is done here or at Monte Lirio, because these stations are in the midst of dense jungle and extensive swamp, where neither oiling nor draining is possible. The only thing done is mosquito catching, and I watched a negro do this. With a "Baldwin candle"—that is, a very small acetylene lamp with a cage over the front instead of a glass—he went about the work in a way which showed he knew what he was about. Two men were employed in this work. We got about half a dozen *Anopheles* in two cars. The occupants are not particular about closing the doors at night; in the evening they often sit on the doorstep holding the door open with their knees. Among ten negro children I found five with enlarged spleen, and two out of three Panamanians were affected. The malaria admission rate from Frijoles is as low as from other stations. The old residents are, I think, probably immune, from former malaria, as they are the inhabitants of old Frijoles.

The employees do not depend for protection on the mosquito catching alone, for they live in screened houses; and as each car is screened separately, this is no inconsiderable degree of isolation. These stations cannot be considered as instances of the value of mosquito catching alone. The good health here results from screening and mosquito catching, and in the old inhabitants probably from the immunity acquired through previous infection.

10.13 The City of Panama

On a rocky promontory jutting out into the Pacific Ocean stands the city of Panama, a quaint mixture of the new and the old world, of bygone and modern days. For it has

grown slowly during three centuries, each of which has left its mark on the place and the people. Begun in the days when pirates and buccaneers were real dangers, when the honest citizen as he retired to rest prayed to be preserved from them that night, and meant it, the city still possesses part of the heavy walls and fortifications designed to keep out these freebooters. Wide modern boulevards cut across narrow passages, and plate-glass windows are intermingled with caged or latticed verandahs. The motor car hustles the mule and the little burro in the street. Celestial and Hindu bargain and trade with the American citizen, the Spaniard, the Panamanian and the San Bias Indian, whose forefathers fought the first European invaders of the Isthmus. True, there is still fighting in Panama, but it is when business is over, or at least suspended, and when the mixture of nations crowd to the prize ring to see what the proprietor advertises as "good, clean sport."

In cleanliness apart from sporting, there has been a change for the better in later days. For pipes now bring pure water from the hills, and the old rain-barrel has disappeared. A sewer system saves the passer-by from a shower of slops from the upper storey, and removes what must always have been an element of excitement when ladies went to shop or promenade in the old days. So times and ways of doing things have changed, and this almost forgotten city has awakened to find itself, not only in the forefront of sanitation, but on one of the great highways of the world.

Yet, with all that has been done for sanitation in the city, I was surprised to find so many flies in the streets. There were more flies than are to be found in places like Singapore, Kuala Lumpur, or Medan, none of which can boast of being any cleaner than Panama. It is true that at long intervals a few flies have appeared in my house at Klang, Federated Malay States; but their appearance has always been the signal for a search for, and the destruction of, the breeding place, which is usually sawdust or the wood refuse of the firewood heap. Stable manure seems to be harmless here; but under no conditions in the Federated Malay States, even when extensive rubbish heaps exist uncovered, have I seen flies such as occur in a dry country like Egypt, or such as compel the inhabitants of the isolated stations in the Mojave Desert of America to screen their houses. I do not pretend to understand this; and I should add it was in Panama City, and not in any other settlement, that I found flies.

11. Panama: antimalarial strategies

11.1 Drainage

Drainage, which Colonel Gorgas puts as first in importance of the anti-mosquito measures, is carried out wherever possible; and indeed one sees it where at first sight it would appear to be of little benefit. On the swamps at the Atlantic side of the Isthmus, where the land and water are almost on the same level, drains have been cut often only nine inches or a foot deep. Yet, wherever it is possible to concentrate the water even in the slightest degree, it is done, for by so doing a great saving of oil is effected. If the water of a swamp can be reduced below the level of the surface of the ground for even only a few weeks in the year, much oil and labour are saved, and a dangerous breeding place is removed. As we have seen, *Anopheles albimanus* is, above all things, a lover of puddles and of the small isolated shallow pools which are so abundant where water stands almost at the ground level. Where the water level is high, every depression in the ground, however small, may at times represent a pool isolated from its neighbours, and seldom containing fish; and since in a swamp the ground is never absolutely level, at times many such breeding places may exist. So on the Isthmus one sees open drains varying from 6 inches deep and 2 feet wide, to great drains 20 feet wide and many feet deep, and every variety of channel which can convey water.

11.1.1 Open drains. These are really extensions of the rivers; and, as I have said, are of every size. The larger channels, drains, and rivers are not considered so dangerous as the smaller drains; for in wet weather, when the current is strong, all larvae are washed away. As will be found, too, from my visit to British Guiana, other conditions exist which make these channels quite harmless. The smaller drains, especially those on the hillsides, are also harmless in very wet weather; but the strong rush of water then erodes the banks, and makes potholes and depressions in bed; and so, although harmless in wet weather, they become dangerous breeding places in dry weather when each depression and pothole is an isolated pool. These drains are kept free from grass as far as possible, and are heavily oiled; but they require constant care, which means expense, and so they are being replaced by other forms of drains whenever practicable.

11.1.2 Tile Drainage. This was introduced by Mr Le Prince as early as 1906. The pipes are laid down in a true grade, and are covered by stone of about 4 to 6 inches in diameter. No earth is put over the stone. “The dirt from the trench must be placed on the downhill side of the line, to prevent it washing back into the ditch. When the soil uphill from the

Figure 11.1 Tile drains ending in an open drain cut in rock, at Gatun, Panama. Men seen in the middle distance of the photograph are relaying the pipes, which had been blocked by grass roots.

ditch is covered with vegetation, the space between the cover-stones does not fill up."[1] This form of drainage has been extensively used, and is being still laid down, as I saw at Gatun; but it is being gradually ousted as favourite by another and cheaper form of drain—the wire drain. The tile drain in Panama has given trouble in two ways. First, because having been covered by a stone that weathered easily and ultimately sealed up the joints, its effective life was only about four to six years; then the drain had to be reopened, and another kind of stone placed over it. Secondly, one of the grasses (cabaloté), when allowed to grow over the stones, found an entrance into the tiles, and blocked them with a mass of roots. In spite of these drawbacks, large areas have been effectually freed from *Anopheles* for many years by these pipes; and the Americans deserve great credit for the manner in which they have developed this important way of eliminating the *Anopheles*.

11.1.3 The Wire Drain. This was introduced by one of the sanitary inspectors, and, on account of its cheapness, it has been very extensively used in the past three years. It costs only 5 cents a foot against 20 cents for a tile drain, and so is displacing the latter. The wire drain is a shallow, open drain, made by putting down a length of wire netting and filling it in with concrete. Where the "seepage" is slight, the drain is only 6 inches wide. From this it varies up to a channel 2 or 3 feet wide "keyed" into the sides.

The tile drain as laid down in Panama would be useless in a ravine in the Federated Malay States, for the friable, sandy soil here would find its way between the stones on the top of the pipe in the first shower, and block it. This actually happened in Kuala

[1] Mr Le Prince in Ross' *Prevention of Malaria*, p. 363.

Lumpur. That it is possible to maintain a wire drain in steep ravines and hillsides in Panama, shows the difference between the soil there and that in the Federated Malay States. In Kuala Lumpur an open cement drain, except at quite a low grade, was found to be useless; for the rate of soil erosion was so great, that after a few showers the open drain was left standing above the ground level, while the stream it was built to carry flowed cheerfully outside.

I wish to insist strongly on the importance of considering the nature of the soil before deciding on the form of drainage. To follow the system of putting large stones on top of the pipes, as is done in Panama, may in other countries mean failure. It was a failure, although not the sole cause of the failure to control malaria, in Kuala Lumpur. On the other hand, having thought out a system of subsoil drainage after having read Howard's *Malaria Prophylaxis in Small Communities in British Central Africa*, in 1907, and before I had heard of what had been done in Panama, I escaped the danger. In Howard's thoughtful account of the malaria of these places in Central Africa, he describes how mosquitoes breed in the streams and along the shore of the sandy island of Likoma, near the eastern shore of Lake Nyassa:

> In the neighbourhood of the lake there are streams which rise as springs in the sand, with a dry watercourse above. They are quite short for the most part, about 100 yards long, and they do not begin to flow until the rainy season has been established a month or so. If the rains come early they may be found running in December, in other years not till February. The actual course of the stream is variable; a sudden rush of rain water will cut quite a new channel through the beach to the lake. A heavy storm brings down quantities of sand which, meeting the waves of the lake, is thrown up as a bar at the mouth of each stream, behind which the water collects as a pond. With every heavy rain the water cuts through this bar and reaches the lake, but during a few consecutive fine days the ordinary flow of the stream escapes by soaking through the sand.
>
> Early in the rainy season fish make their way up the streams to spawn, so that the ponds and streams are soon full of young fry. These effectually destroy Anopheline larvae, and at the beginning of the wet season the latter are only found where they are out of reach of the fish. Such places, however, are only too plentiful. Reeds or grass may grow in the course of the stream and so give shelter, or some slight obstruction may cause an eddy which during a rainstorm scoops out a pool in the sand. As the water subsides, the pool is left securely shut off from the main stream, which contains fish, and is kept fresh by the soakage through the sand of the water running close to it. Such pools form ideal breeding places, and are often crowded with larvae.
>
> At first sight, the destruction of Anopheline breeding places in an island like Likoma might appear easy, but in practice the uncertain course of the streams through the sand, and the rise and fall of the lake, make it impracticable. Even if regular brick drains were made, it would be quite likely that the rush of water, bringing down tons of sand from above, would block them up, and cut a new channel for itself. Moreover, the cost of such a scheme would be prohibitive, for lime cannot be procured less than 100 miles away, and costs £6 per ton, while cement from England costs nearly £17 per ton. Lastly, owing to the quantity of sand which the water brings down, coupled with the annual rise and fall of the lake, it is impossible to prevent the formation of a bar with the pond behind it at the mouth of such stream.

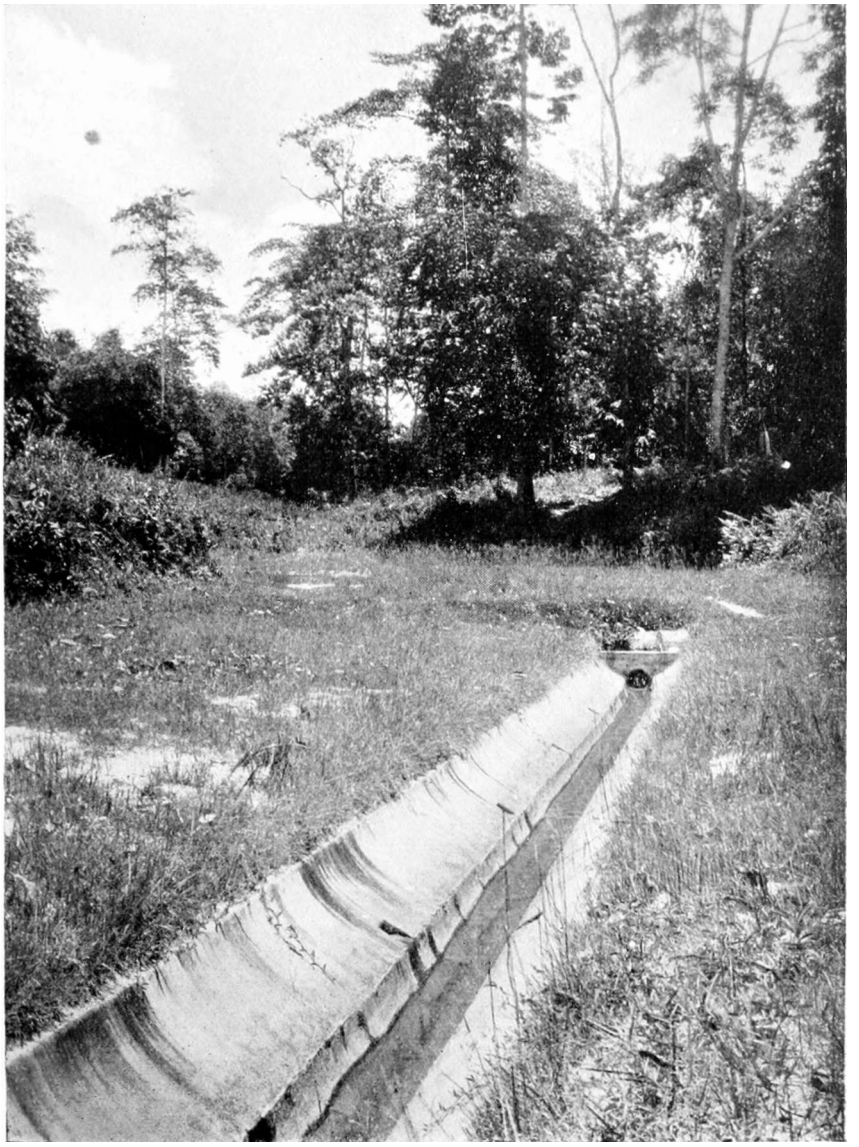


Figure 11.2 An open cement channel in the Federated Malay States, which had to be replaced by a subsoil pipe in the steeper portion of the ravine because of the soil erosion. Such a channel as this could be put down anywhere in the Canal Zone without any such risk.

Reading over this account, and wondering how the pools in the streams could be abolished, it struck me that a pipe buried in the ground with grass allowed to grow over it to stop erosion, was the solution of the difficulty; and that if cement and kerosene were high-priced commodities there, clay certainly would be cheap, and the manufacture of tile pipes present no great difficulty. And so, when I thought of using tile pipes for the

first time, it was for an island in Central Africa, not for the Federated Malay States; but in September 1908, after the matter had been discussed with Mr J. Scott-Mason, late acting Governor of British North Borneo, then chairman of the Klang Sanitary Board, and with Mr John Gibson, the general manager of the Tremelbye Rubber Company, Limited, some pipes were made for the Board by Mr Low Joy of Klang. They were not laid down, however, as Mr Simm's paper in the *Annals of Tropical Medicine and Hygiene* showed the Americans had employed tile drains in Panama for well over a year before the idea had even occurred to me.

Later still, in 1909, when I had come to the conclusion that our hill land differed radically from the flat land, and would never become healthy like the flat land through cultivation, I reverted to the idea of the tile drain; but I insisted the pipes should be laid down according to my original method, and not as was done in Panama. And so from the first, on estates in the Federated Malay States, the pipes have been buried in the earth and no stones have been placed over them.

I have thought it necessary to go into this matter, because it serves to emphasise the supreme importance of every man in charge of anti-malaria work thinking out every detail for himself, and weighing carefully the local conditions. Merely to copy faithfully what is a success in another place does not by any means guarantee success.

Although drainage has been extensively carried out and has been of great value, it seems to me to be quite secondary in importance to oiling on most of the zone. When it has been possible to lay down a permanent drainage system, as has been the case in a few places, e.g. in part of Gatun, mosquito breeding places have been permanently abolished, and oiling is unnecessary. No other measure directed against the mosquito and against malaria is so simple and permanent as drainage; and hence Colonel Gorgas places it first in order of importance,[1] and Mr Le Prince says: "Drainage and eradication of breeding areas is the all-important work in an anti-malarial campaign."[2] But it seems to me the supreme merit of the Panama work that, not being in a position to apply the best method which at one stroke would have given success, they have yet achieved almost complete success by a combination of other and inferior methods, which have required the highest degree of organization and infinite care, not for a day or a month, but for over a whole decade. Their position has been as if they had a wild beast by the throat, but were not allowed to kill it; yet, if for a moment they relaxed their grip, the beast would be on them.

I have shown how at a number of stations, e.g. Ancon, Matachin, Culebra, etc., drainage systems have been destroyed by "dumping." In some stations breeding places could not be drained for want of "fall;" in others nothing permanent has been laid down, because the place would be abandoned on completion of the Canal; and in others, new breeding places were constantly being made. And so, for one reason or another, the Sanitary Department have not been in a position to construct what they desired—a permanent drainage system—but have been compelled to leave the breeding places and kill the larvae in them every week—truly a Sisyphean task.

[1] Ross' *Prevention of Malaria*, p. 347 [2] *Ibid.*, p. 363.

Table 11.1 Cost of oiling and larvicide use in the Panama Canal zone in March 1913

Item		Cost	Sum
larvicide spreading	labour	$1395.00	
	material (8910 gallons)	$1556.00	
			$2951.00
Oil spreading	labour	$1584.93	
	material (50,441 gallons)	$1297.41	
			$2882.34
Total			$5833.34

To have, by oiling, to eradicate malaria over an area of 50 square miles of country, where the water appeared in every conceivable form, in springs, in pools, in rivers; and bottomless swamps, was a task which would have daunted all but men confident in the scientific basis of their practice and determined to succeed. Colonel Gorgas did not hesitate, and at once proceeded to build up an oiling system which would give the best results at the minimum cost; for throughout economy has been considered as carefully as efficiency.

To reduce the handling of oil to a minimum, the Sanitary Department has tanks at many stations connected with the trans-isthmian pipeline. Pipes are also laid on the places which require much oil, or where carriage presents special difficulties, as in the bottom of the cut. In some places mules carry oil to the men; in other places an oil cart sprays oil onto the roadside ditches; oil drips from barrels on to the streams; and cotton waste, soaked in oil and anchored in springs, gives off a constant film. When swamps are deep and extensive, boats fitted with sprayers spread the oil.

11.2 Oiling

In every way the number of labourers is reduced. At one station I found 35 gallons of material (a mixture of oil and larvicide) had been spread in half a day by four men, who were supplied with the oil by three men carrying it from the depot. That is, it costs seven dollars in labour to spray one dollar's worth of material. This is much above the average for the whole zone; but it shows how important it was to economise labour. The actual figures for March, 1913, for the whole zone are listed in Table 11.1. The total cost of unskilled labour, material, and supplies on the Canal zone in 1911–12 is given in Table 11.2. It amounts to $116 per square mile, or 18 cents per acre per month.

In Panama, crude oil, used also as fuel for engines, costs only $1.10 (gold) for a barrel containing 42 gallons. In the Federated Malay States the price has, in the last few years, risen to three times what it is in Panama.

11.2.1 Sprayers. The machine used in Panama is the Meyer's Knapsack Sprayer. From the photograph in Figure 10.11 it will be seen that a long lever projects over and above the man, and this is pulled down by means of a rope to put the sprayer into action. It

Table 11.2 Cost of labour and supplies for sanitary work in the Canal Zone, in 1911–12

Item	Cost
Labour, silver employees	$79,499.19
Material and supplies	$53,185.11
Total	$132,684.30

is easier to work this pump than those, like the "Vermorel," where the handle is on the side of the pump, and is moved by a downward push of the hand.

11.2.2 Drip Barrels. The commonest form of this is a 30-gallon galvanised iron ash can,[1] into the side of which an opening about 2 inches wide and 3/8 of an inch in height is made. "Into this opening is soldered a flat spout 1 3/4 inches wide, 1/4 inch high, 2 1/2 inches long, into which is inserted an ordinary wick," such as is used in a spirit lamp. The rate of flow is regulated by compressing the spout until the oil drips with sufficient rapidity to give a good oil film. "The heavy oil used by us has a tendency to clog the wick. The clogging, is to a certain extent, prevented by putting into the bottom of the can sufficient water to reach within an inch or so of the wick. This water acts as a settling basin for impurities heavier than oil. In addition it is often necessary to 'cut' the oil by the addition of from 5 to 10 percent of the larvicide."

"In order to be efficient, the drip can must be placed 2 or 3 feet above the surface of the water to which the drip is to be applied, so that the drops may strike the surface of the water with sufficient force to be broken up." All the barrels in a district are numbered and shown on the Sanitary Department's plan. One man is employed to keep them filled; and the inspector must see them each week. On some stations the drip is regulated by a screw; but it is doubtful if this is as efficient as the wick.

11.3 Larvicide

As the Sanitary Department found no larvicide was reliable, and all were very expensive, the manufacture of a good larvicide was begun at Ancon, in a shed connected by rail with the main line.

The details of the manufacture were worked out by Mr J. E. Jacob, chemist, Board of Health Laboratory. The work has been described as follows:[2]

> In the work of destroying algae and mosquito larvae in the Canal zone, large quantities of the larvicide are used, the amount averaging 250 barrels a month, and a plant erected for its manufacture has been in operation for two years.[3]
>
> The larvicide is prepared from crude carbolic acid, a substance which as usually applied contains from 5 percent to 10 percent tar acids, together with a large amount of inert neutral oils. The crude acid is immiscible with water, and is a very inefficient disinfectant on account of its inability to come into intimate contact with microorganisms.

[1] Dr Orenstein, "Sanitary Inspection of the Canal Zone," *American Journal of Public Health*, March 1912.
[2] "A Mosquito Larvacide-Disinfectant and the Methods of its Standardization," by S. T. Darling, *Amer. Journ. of Pub. Health, Feb. 1912.* [3] i.e. since 1910. – M. W.

> When, however, the crude carbolic acid is made into a liquid soap with rosin and alkali by means of heat, a product results which emulsifies upon the addition of a large amount of water. If the germicidal value of the emulsion is determined by the method of Rideal and Walker it will be found to be greatly enhanced, frequently being from two to five times greater than that of pure carbolic acid.
>
> The product is not only a most effective destructive agent for mosquito larvae, but is a valuable and cheap disinfectant.
>
> Method of manufacture: To ensure the manufacture of a uniform product, requisitions call for crude carbolic acid of a specific gravity not greater than 0.97, and to contain not less than 15 percent of tar acids. Each consignment of crude carbolic acid received is assayed at the laboratory to determine its specific gravity and percentage of tar acids, for it is necessary to keep the product of a specific gravity approximately that of water, so that it will diffuse rapidly, and neither sink to the bottom nor remain on the surface.
>
> One hundred and fifty gallons of crude carbolic acid are heated in an iron tank, having a steam coil with steam at 50 lbs. pressure. Two hundred pounds of finely crushed and sifted common rosin are dissolved in the heated acid, and then 30 lbs. of caustic soda dissolved in 6 gallons of water are added. There is a mechanical stirring rod attached to the tank. The product is ready in a few minutes, yielding about $3^1/_2$ barrels.

The cost of manufacture, as given in the same reference, is listed in Table 11.3.

On mixing the larvicide with water it forms a white mixture something like Jeyes' fluid. In a dilution of 1 in 5000 all larvae will be killed in five minutes, and 1 in 8000 will kill them in thirty minutes. The larvicide also kills algae on which the larvae feed, and is also destructive to other vegetable matter. The decomposition set up by this dead matter causes a pellicle to form on water, and thus further makes the water unfit for mosquitoes, even after the larvicide has itself disappeared.

The larvicide is used as a disinfectant for all sorts of things in the zone, e.g. privies, as well as to destroy larvae in water. It is also a very convenient preparation, because it does not burn the hands unless employed in full strength, and then for a long period.

It has, however, two very serious limitations: one is, that it loses its efficiency when exposed to the air for more than a hour; the other is, that it is ineffective in sea or brackish water. To prevent deterioration it is kept in a tightly closed container. "Larvicide shipped in barrels should not be kept longer in them than necessary," says the Sanitary Inspector s Manual. The inspectors are also warned that "larvicide is an expensive product, and should be used in sufficient, but not in excessive quantities."

11.4 Screening

Screened houses are much used in the United States. In New Orleans the best houses had a portion of the verandah screened, and had frames fixed to all windows, so that even when the glass frame was thrown up the house remained mosquito-proof. In Panama the Americans invented quite a new style of mosquito-proof dwelling. It is so new that the skill of the architect has not yet had time to relieve it of an uncompromising, almost puritanical plainness, which is accentuated by the outside colour scheme being a dismal drab or slate. All the houses are simply rectangular boxes, with some partitions inside to form the rooms, and screening over the whole of the verandahs. The boxes are

Table 11.3 Cost of larvicide manufacture, August 1909. The total amount manufactures was 14,600 gallons (292 barrels).

Item	Amount	Price	Extended Price
Carbolic acid, crude	12,600 gallons	12 cents/gallon	$1,512.00
Rosin	12,300 lbs.	$2.48/100 lbs.	$305.04
Caustic soda	2,550 lbs.	$3.70/100 lbs.	$ 94.35
Coal	2 tons	$5/ton	$10.00
Labour			$92.46
Supervision			$50.00
Total			$2,063.85

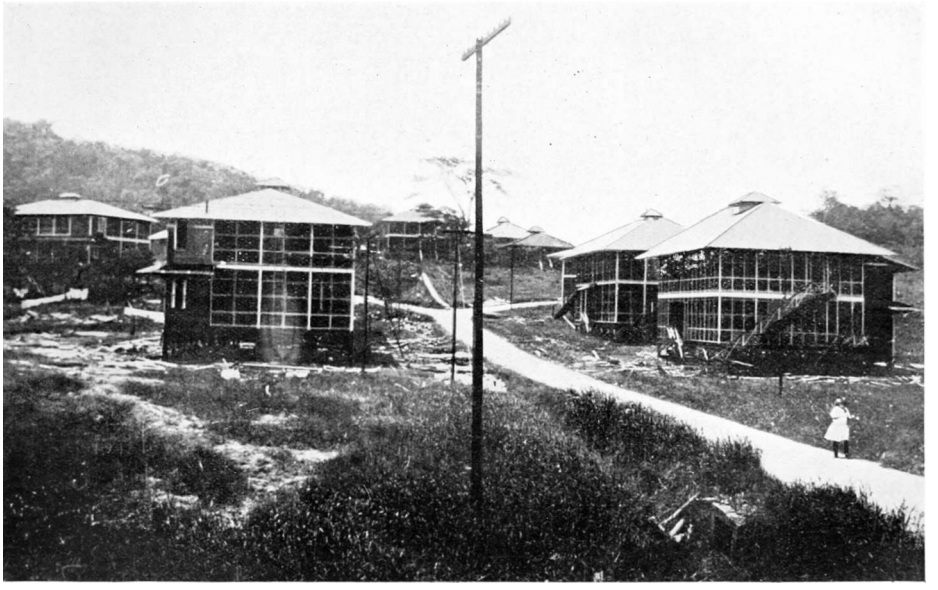
made in many sizes, but the shape never varies. Some contain one family; others are so divided that two families live upstairs and two downstairs. The higher officials have larger houses still; but each and all are of the same design, and all are built of wood. All are provided with water supplies, bathrooms, and water-closets. The kitchens are inside the houses; not separate, as is the custom in the East.

The wire gauze used to screen the houses is made of pure copper and zinc, for it is found that the admixture of even 1 percent of iron materially shortens the life of the gauze. It is obtained from three firms: The Clinton Wire Cloth Company, New York; the New Jersey Wire Cloth Company, New Jersey; and the W. S. Tyler Company, Cleveland, Ohio. Eighteen strands to the inch is the mesh used on the zone. When it shows signs of gathering dust, water is sprayed on to it from a hose.

None of the houses have "rotan chicks," nor did I notice any kind of sunblind. To protect a house the gauze is applied to the outside of the verandah, or where there is no verandah it covers the window. Both on the verandahs and windows the gauze is fixed, and there are no openings into the house except doors. Doors open outwards; and it is not considered necessary to use double doors. By making the door open outwards, any mosquito which happens to be sitting on the door when it is opened is thrown outwards; were the door to open inwards, it is probable the mosquito would pass into the house in front of the person opening the door. The screening of all houses is regularly inspected and repaired if necessary.

As so much is made by some critics of the difficulty of keeping screening intact, I specially noted the condition of the screening on the zone. On only three occasions did I observe damage. The worst damage was at Ancon Post Office, where the screening on the doors had large holes in it. This is a busy office, and the screening obviously required more than the usual protection of wooden spars if it was to stand. At Colon I noted damage to the door of one store and one dwelling house. I was told that the negro and Spanish employees often damage it in the most malicious way; but if so, it is promptly repaired. I wish to state very emphatically, and as the result of careful examination of houses during my stay on the zone, that the screening is maintained in good order, and in my opinion no one should have any difficulty in repeating what has

A



B

Figure 11.3 Screened houses in Panama. A: Houses for four families at Corozal. B: House occupied by the Sanitary Inspector at Frijoles.

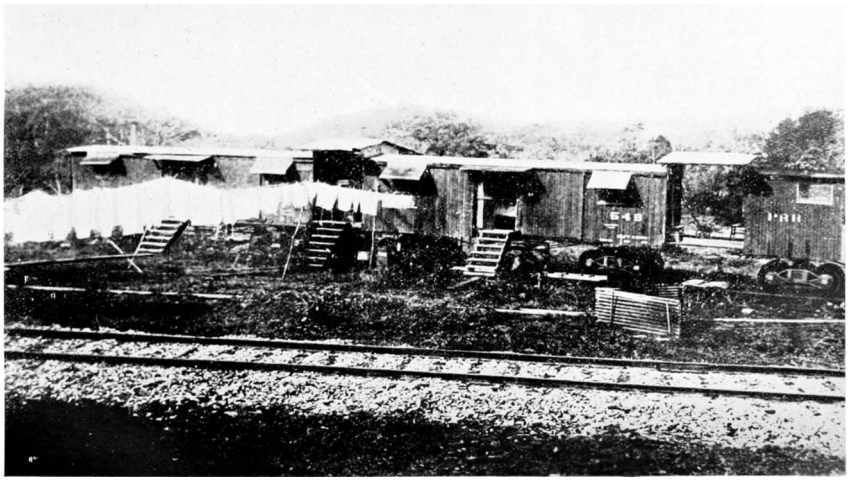


Figure 11.4 Screened railway wagons on the Panama Railroad used as dwelling-houses.

been done in Panama with any class of labour, if he takes an interest in it. It is, however, of the greatest importance to get a material which, being free from iron, will not rust.

It is sometimes stated, as another objection to screened houses and hospitals, that they are mosquito traps: that mosquitoes get in and cannot get out again. It is certainly true that some mosquitoes find their way into screened houses; but the number that does is very small indeed compared with those that find their way into unscreened buildings. The fact that screened houses are a trap cannot be denied; but there is a silver lining to the cloud; for most of the mosquitoes that enter will be found in the early morning on the screening, where it is easy to catch and kill them in a wide-mouthed bottle containing a plug of cotton-wool soaked in chloroform or tobacco juice. Even if the mosquitoes are not so killed, their life in the house will last only a few days unless they get water. It has been observed that mosquitoes in a screened house during the day make for flower vases, sinks, and other collections of water, without which they soon die. On the advantage of trapping and killing *Anopheles* which may have bitten malaria patients in hospital, over allowing them to fly free every morning only to reinfect the patient again in the evening, or to infect the healthy inhabitants of the neighbourhood, it is unnecessary to speak. The value of screening is here overwhelming.

Although all Commission quarters were screened when the Americans first settled on the zone, by 1909 it was realized that screening was not so important as it had been; and circular No. 420, issued by the chief sanitary inspector on the 13th August of that year, marks in a very definite way the change of opinion. That circular stated that no new screening was to be put onto “married silver quarters;” nor was that already in existence to be repaired. The reason for this order was as follows: The Canal zone not being a colony where both men and women are wanted, the Commission, although anxious to attract labour in 1905, were not willing to spend much on accommodation for women, and in fact provided accommodation for only a comparatively few married

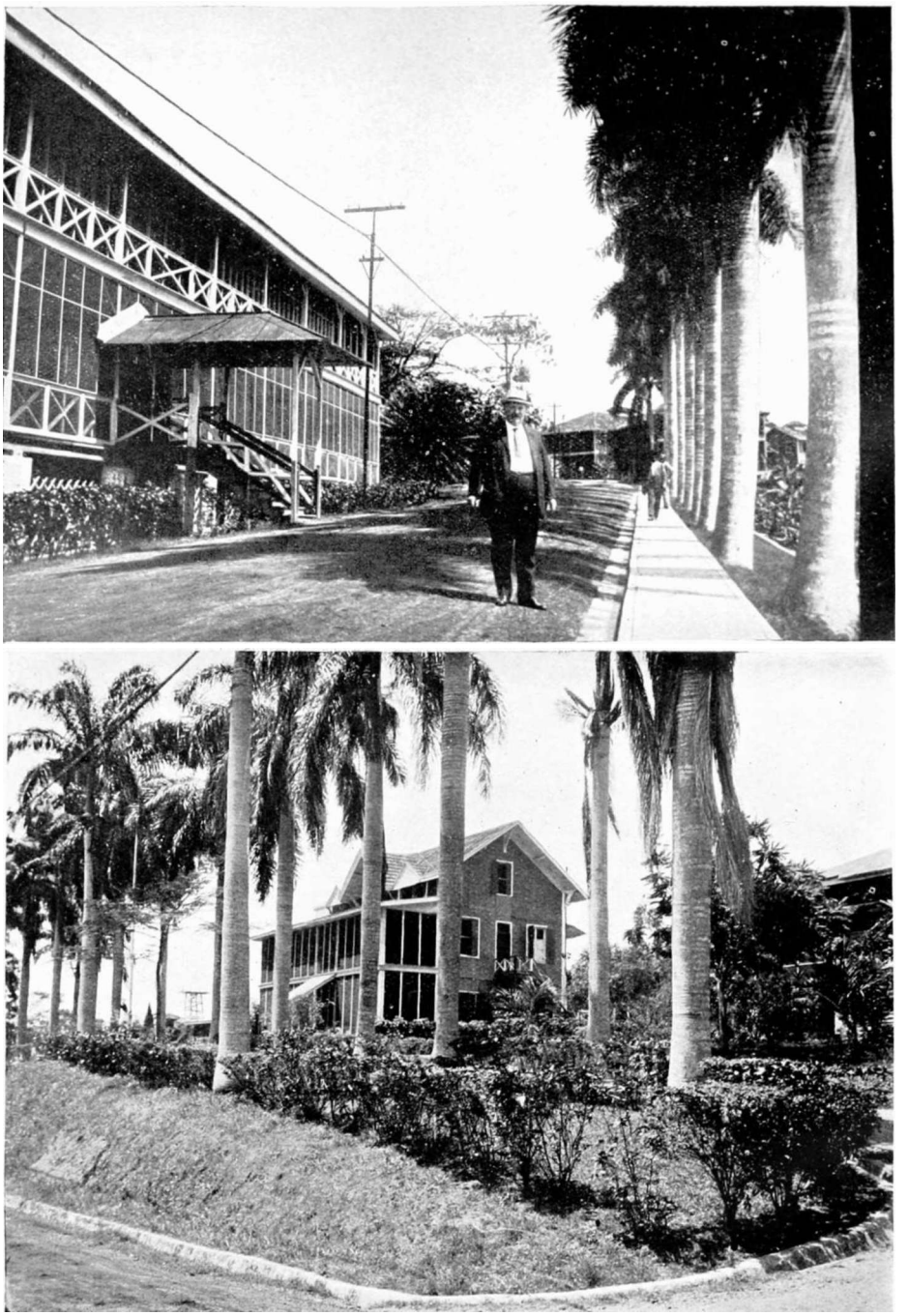


Figure 11.5 Ancon Hospital, Panama. Built by the French. A: One of the wards, now screened. B: A house converted to screend quarters.

Table 11.4 Number of Canal Zone residents living in screened houses as of June 30th, 1912. The total population was 146,510.

Americans	8,908
Europeans	5,558
West Indians	8,915
Total	23,381

negroes. It was sufficient, however, for the requirements; for in 1906 the zone had still a bad name, and did not attract married labour.

But with the marked improvement in health in 1907, negro labour came in freely, and the women began to come with their husbands. By 1908 the zone, from its high rate of pay, was very popular; and there now being married couples far in excess of the accommodation provided by the Commission, the negroes either hired houses, which were springing up on the outskirts of the stations, or built huts ("shacks") for themselves. As these privately built houses or "shacks" were not screened, the Sanitary Department protected the occupants from malaria by extending the area treated with oil. So it came about that, instead of oiling and draining for only 200 yards round houses, the Department found it had to extend its operations for half a mile round each station, which was the situation when I paid my visit. When it was seen that the married labourers and their children in unscreened houses kept free from malaria, it was decided to stop screening the Commission quarters occupied by married negroes, that is, the "silver married quarters."

Although Colonel Gorgas says:[1] "Personally I lay great stress on screening. I would have it done always in the tropics. In early work, before mosquitoes are destroyed, screening is a great help. We are never sure enough of the disappearance of the mosquitoes to do away with screening. It is much preferable to live in screened houses than to be constantly taking prophylactic or malarial treatment. Of course, there will always be cases of malaria now and then, even in the best protected places."

Although even now all quarters except those occupied by the "silver married" employees are screened, the freedom from malaria of the non-employees and of the employees who lived in unscreened houses, shows clearly that by 1909 the oiling and drainage carried out on the zone were in themselves sufficient to control the disease and reduce its incidence to a negligible quantity. So far as I can learn, the total number of those who, on 30th June, 1912, lived in screened quarters on the area controlled by the Sanitary Department was only 15 percent (see Table 11.4).

11.5 Quinine

When the Sanitary Department first began work, it employed seventeen quinine dispensers, who visited the various squads of negroes at work and offered it to the men. The drug was also given gratis to all who applied for it at the dispensaries, and it was

[1] Discussion on Dr Orenstein's paper, "Screening as an Anti-malarial Measure," *Engineering Record*, 29th June, 1912

placed on all the hotel and mess tables. No attempt to compel people to take it was ever made. In 1909, Mr Le Prince estimates, “about half of our force gets a prophylactic dose of quinine each day.” But by 1913 I found that very few indeed took the drug except when actually ill with fever; and only two quinine dispensers were employed. It was clear that the good health of the zone did not depend on the inhabitants taking quinine.

12. Panama: on mosquitoes

12.1 *Aedes calopus* (*Stegomyia fasciata*) and yellow fever

It is not my purpose here to say much more on the Panama work on yellow fever, or the destruction of *Aedes calopus*. Even after the water supply had been laid onto the city of Panama, yellow fever persisted, and it was necessary to make a minute house-to-house examination for the various breeding places of the yellow fever mosquito. Many of these places were small and never suspected. Some were so hidden away that they baffled detection for days; often it was only the continued presence of the insects that told the inspector some place had still been overlooked, and stimulated him to further search. Four times every house in the city was disinfected with sulfur, after being carefully sealed up; and only then did yellow fever disappear; that is eight years ago.

Aedes is a mosquito that lives only in rainwater collections near to human habitations, and never once has it been found in a pool on the ground.[1] A proper water supply from pipes to replace the rainwater caught by each householder in barrels, was the chief means of stopping yellow fever. After pipe-water had been supplied and the old water containers abolished, yellow fever disappeared. Then the cloud whose darkness threatened Asia almost with the fate of Pompeii, lifted, although it has not completely melted away.

12.2 Asia's Danger

At the end of *Kwaidan*, in which Lafcadio Hearn has so exquisitely retold some of the weird tales from the old Japanese books, he has added three insect studies—butterflies, mosquitoes, ants. That on mosquitoes I cannot help reproducing almost in full, for reasons which will be apparent.

> With a view to self-protection I have been reading Dr Howard's book, *Mosquitoes*. I am persecuted by mosquitoes. There are several species in my neighbourhood; but only one of them is a serious torment—a tiny needly thing, all silver-speckled and silver-streaked. The puncture of it is sharp as an electric burn, and the mere hum of it has a lancinating quality of tone which foretells the quality of the pain about to come—much in the same way that a particular smell suggests a particular taste. I find that this mosquito much resembles the creature which Dr Howard calls *Stegomyia fasciata*, or *Culex fasciatus*, and that its habits are the same as those of the *Stegomyia*. For example, it is diurnal rather than nocturnal, and becomes most troublesome during the afternoon. And I have

[1] "Some Problems of Mosquito Control in the Tropics," by Allan R. Jennings, Inspector Entomologist, Panama Canal Zone, *Journal of Economic Entomology*, vol. v., No. 2, 1912.

discovered that it comes from the Buddhist cemetery—a very old cemetery—in the rear of my garden.

Dr Howard's book declares that in order to rid a neighbourhood of mosquitoes, it is only necessary to pour a little petroleum, or kerosene oil, into the stagnant water where they breed. Once a week the oil should be used, 'at the rate of one ounce for every fifteen square feet of water surface, and a proportionate quantity for any less surface.' … But please to consider the conditions in my neighbourhood!

I have said that my tormentors come from the Buddhist cemetery. Before nearly every tomb in that old cemetery there is a water receptacle, or cistern, called *mizutamé*. In the majority of cases this *mizutamé*, is simply an oblong cavity chiseled in the broad pedestal supporting the monument; but before tombs of a costly kind, having no pedestal-tank, a larger separate tank is placed, cut out of a single block of stone, and decorated with a family crest, or with symbolic carvings. In front of a tomb of the humblest class, having no *mizutamé*, water is placed in cups or other vessels—for the dead must have water. Flowers also must be offered to them; and before every tomb you will find a pair of bamboo cups, or other flower-vessels; and these, of course, contain water. There is a well in the cemetery to supply water for the graves. Whenever the tombs are visited by relatives and friends of the dead, fresh water is poured into the tanks and cups. But as an old cemetery of this kind contains thousands of *mizutamé*, and tens of thousands of flower-vessels, the water in all of these cannot be renewed every day. It becomes stagnant and populous. The deeper tanks seldom get dry—the rainfall at Tokyo being heavy enough to keep them partly filled during nine months out of the twelve.

Well, it is in these tanks and flower-vessels that mine enemies are born: they rise by millions from the water of the dead; and, according to Buddhist doctrine, some of them may be reincarnations of those very dead, condemned by the error of former lives to the conditions of *Jiki-ketsu-gaki*, or blood-drinking pretas. … Anyhow, the malevolence of the *Culex fasciatus* would justify the suspicion that some wicked human soul had been compressed into that wailing speck of a body.

… I wonder what would be said if the city government of Tokyo—which is aggressively scientific and progressive—were suddenly to command that all water surfaces in the Buddhist cemeteries should be covered, at regular intervals, with a film of kerosene oil! How could the religion which prohibits the taking of any life—even of invisible life—yield to such a mandate? Would filial piety even dream of consenting to obey such an order? And then to think of the cost, in labour and time, of putting kerosene oil, every seven days, into the millions of *mizutamé*, and the tens of millions of bamboo flower-cups in the Tokyo graveyards! … Impossible! To free the city from mosquitoes it would be necessary to demolish the ancient graveyards—and that would signify the ruin of the Buddhist temples attached to them—and that would mean the dispartition of so many charming gardens with their lotus-ponds and Sanscrit-lettered monuments and humpy bridges and holy groves and weirdly smiling Buddhas! So the extermination of the *Culex fasciatus* would involve the destruction of the poetry of the ancestral cult—surely too great a price to pay! …

Besides, I should like, when my time comes, to be laid away in some Buddhist graveyard of the ancient kind—so that my ghostly company should be ancient, caring nothing for the fashions and the changes and the disintegrations of Meiji. That old cemetery behind my garden would be a suitable place. Everything there is beautiful with a beauty of exceeding and startling queerness; each tree and stone has been shaped by some old,

> old ideal which no longer exists in any living brain; even the shadows are not of this time or sun, but of a world forgotten, that never knew steam or electricity, or magnetism or—kerosene oil. Also in the boom of the big bell there is a quaintness of tone which wakens feelings so strangely far away from all the nineteenth-century part of me, that the faint blind stirrings of them make me afraid, deliciously afraid. Never do I hear that billowing peal but I become aware of a striving and a fluttering in the abyssal part of my ghost—a sensation as of memories struggling to reach the light beyond the obscurations of a million million deaths and births. I hope to remain within hearing of that bell. … And, considering the possibility of being doomed to the state of a *Jiki-ketsu-gaki*, I want to have my chance of being reborn in some bamboo flower-cup, or *mizutamé*, whence I might issue softly, singing my thin and pungent song, to bite some people that I know.

The boom of the big bell with its billowing peal, with its quaint tone, stirs a chord of sympathy with the lover of that Buddhist graveyard in the heart of the sanitarian. And if those charming gardens, and lotus ponds, and holy groves, and all the poetry of the ancestral cult, pleading to be spared, hold for a moment his profaning hand, and make him realise the mighty forces at times arrayed against him, surely it will not be recorded that he was false to his charge. And yet this Buddhist graveyard with its tens of millions of little bamboo flower-cups, each and all a token of love and emblem of eternal life, might have bred death to the hundreds of millions who live in Asia; and had yellow fever not been stamped out on the Canal, can we doubt that the religion which prohibits the taking of life would have turned Asia into a shambles?

With the myriad mosquito breeding places in Japan, and the countless myriads in all Asia, the disease would have flashed from east to west leaving millions of human beings rotting, unburied, in heaps. Nothing the world has known, hardly anything we can imagine, all Asia crammed into a Black Hole of Calcutta, sketches even an outline of the disaster it would have been to the human race.

Time and again improved communications have led to the introduction and spread of disease; and all should rejoice that the American sanitarians, by their work in Havana and in Panama, have made it practically certain that yellow fever will never be allowed to reach Asia directly from America. Surely there was a Controlling Power who delayed the construction of the Canal until men had learned how to control yellow fever! But although the danger of yellow fever reaching Asia has been averted for a while, it would be folly to assume the comfortable attitude that all is well. Every Asiatic port is full of *Aedes calopus*, although all perhaps cannot rival Tokyo. Singapore is no exception; and if I refer to it now, it is because the subject is receiving attention. Anti-malaria work was specially urgent in 1911, so general anti-mosquito work was put aside for the time. The arguments in favour of anti-yellow fever work are, however, strong; and the following is an extract from my report to the Government of the Straits Settlements:

> Were yellow fever to reach Asia, Singapore would, from its position on the great highway, become infected at a very early date; and through its great distributing trade it would, if once infected, act as the great distributor of the disease, despite all the quarantine restrictions that would be put on Singapore ships by neighbouring countries.
>
> Perhaps it may be thought that there is no possibility of yellow fever reaching Asia. Of that I am by no means sure. Certainly, with the eradication of the disease from the

Panama Canal zone, the risk of the disease being brought to Asia by ships passing straight through the Canal has been reduced practically to zero; but as the Canal will attract steamers and create a new sea-highway, there is always the chance that some tramp steamer using the Canal to reach one of the many infected Central or South American ports, may carry infection to one of the Pacific Islands; and that infection may reach Asia via the equatorial islands; nor need this involve any long period of time, certainly not enough to allow Singapore to put its house in order, if nothing has previously been done. Were the disease to come in this way, Singapore would probably be the first Asiatic port to become infected.

But there is another source of danger to Asia, to which, until now, the British have not given attention; the American mote has been more apparent than the British beam. I refer, of course, to the yellow fever which exists in West Africa. When we remember that yellow fever has on repeated occasions spread from West Africa to Spain, and even farther north, we can only conclude it has not reached Asia via the Mediterranean because there is no direct and practically no indirect trade between these points. But are we quite safe in assuming that this immunity will last? The development of Africa makes great strides, and it does not seem to me that it is a danger to be disregarded.

Finally there is another route by which yellow fever may reach Asia from West Africa. Up till now the disease has been confined to the equatorial portions of West Africa; it has been unable to spread much along the coast either north or south, because the trade routes do not lie in these directions; nor has it been able to spread far inland or across the continent, because on the high plateau which occupies the whole of the centre of the continent the temperature is below that necessary for the parasite's development in the mosquito. At the present time, were a freshly infected man to leave the west coast for the east coast, his progress would be so slow that at the very most he could only reach the cold plateau before the disease showed itself; and as he is infectious for only three days, there would be no chance of his ever infecting mosquitoes on the east coast. But were a trans-continental line constructed—and proposals have, I believe, already been made to connect the existing lines that now run inland from the east and west coasts—it would easily be possible for a man infected on the west coast to travel to the east coast during his incubating period, and so start the disease there. To India, then, would be but a short step. Indeed, given the trans-African railway, nothing will stop yellow fever traveling by it, except the eradication of the disease from the west coast previous to its construction.

That railway may not come today or tomorrow, but come it will some time; and anxiously we may peer into the future, to find what it will bring to Asia and to Singapore. I do not propose to assume the prophet's robe, yet I make bold to say that Singapore's danger may be measured by the extent of her neglect in the near future to exterminate the yellow-fever mosquito within her gates. For if Singapore fails to realise how great a stake in wealth as well as health, in trade no less than in happiness, depends on her decision now, and neglects to take the precautions to preserve her freedom from the disease, we may be quite sure that Africa is no less likely to fail to take such steps as will prevent the disease spreading to Asia.

12.3 *Anopheles* and malaria

Since the yellow-fever mosquito bred only in artificial vessels and situations, its destruction was comparatively easy, and yellow fever was soon stopped. But with *Anopheles* and malaria the conditions were entirely different, indeed almost the reverse. Except

Table 12.1 *Anopheles* species identified in the Panama Canal Zone

Anopheles	*albimanus*, Weid.	*Anopheles*	*apicimacula*, D. K.
"	*tarsimaculata*, R. D.	"	*gorgasi*, D. K.
"	*argyritarsis*, R. D.	"	*cruzi*, D. K.
"	*pseudopunctipennis*, Theob.	"	*eiseni*, Coquill.
"	*franciscanus*, M'Crack.	"	*punctimaculata*, D. K.
"	*malefactor*, D. K.		

on two occasions to which I shall refer, *Anopheles* on the Canal zone have never been found except in water on the ground; although some species, probably unimportant as far as malaria on the zone is concerned, breed in water collections in trees. And since, from the nature of the engineering works, it has not been possible to abolish all the breeding places of the *Anopheles*, malaria has not been abolished on the zone; although at a comparatively early date it ceased to be of serious concern.

12.3.1 The species of *Anopheles* on the Zone. No less than eleven species have been collected (see Table 12.1), yet it is improbable that more than three are of economic importance from carrying malaria.

It is not unlikely that *tarsimaculata* is a variety of *albimanus*, since it differs from it only in the arrangement of the white bands in the palpi. It is also probable that *A. gorgasi* is an abnormality of *tarsimaculata*; only one specimen has been found, and it is somewhat damaged.[1]

12.3.2 *Anopheles albimanus*. "The most important and the most easily recognised species among our American *Anopheles* is *Anopheles albimanus*, Weidemann," writes Mr Knab.[2] And this being so, it will give some idea of the difficulty there has been in determining accurately what mosquitoes exist in a place, if I repeat from Dr Knab's paper the various names and combination of names which have been applied to this easily recognized insect (see Table 12.2). It has had an even more confusing nomenclature than *A. maculatus* (or *willmori*) in Asia. As will be seen later on, this mosquito exists in British Guiana, and it is the great malaria carrier in tropical America and the West Indies.

On the Canal zone *A. albimanus* is not only the most important *Anopheles*, but it is the commonest. Although it cannot breed in swiftly running water, it can and does breed in the grass of sluggishly running water, in isolated pools, in stream beds, and in backwaters, especially where there is a growth of algae. Although it is considered necessary to oil the sides of the lake at Pedro Miguel, it may be said that the mosquito does not like the larger collections of water; marked sewage contamination, too, is un congenial, indeed is inimical to the larvae, but they have been found where pollution is slight.

[1] "The species of *Anopheles* that transmit malaria," by F. Knab, *Americal Journal of Tropical Medicine*, 1913.
[2] *Ibid.*

Table 12.2 Alternative species names of *Anopheles albimanus*

Genus name	Species name	Named by
Anopheles	*cubensis*	Agramonte
"	*dubius*	Blanchard
"	*argyritarsis*, var. *albipes*	Theobald
"	*albipes*	Howard
Cellia	*argyritarsis*, var. *albipes*	Goeldi
"	*albipes*	Giles
"	*albimana*	Theobald
Nyssorhynchus	*cubensis*	Blanchard
"	*albimanus*	Surcouf and Gonzalez-Rincones

"With the exception of foul or swift water, they may occur in almost any collection of water, however small or seemingly unsuited to mosquito propagation. Hoof-prints, wheel-ruts, the smallest puddle or thinnest film of water seeping upon the ground from a wet hillside, particularly if the ubiquitous algae are present, are points of danger, and must be included in the control work. … While not domestic in the same sense as *Stegomyia calopus*, *Anopheles albimanus* is closely associated with man, and finds its most congenial surroundings about his habitations, and in the conditions he creates in the course of agricultural, engineering, and other works."[1]

The outstanding impressions I received of this mosquito were, first, that it is essentially a puddle-breeder, preferring the smallest puddles it can get, although to be found in other places where the other conditions were favourable; and secondly, that the existence of algae, or the presence of dead grass, dead wood, and other dead vegetable matter created, above all, a condition favourable to it, and that where the conditions were favourable the insect might be found in enormous numbers.

Near to dwellings and to man's work the conditions are inimical to vegetation, and so favourable to the mosquito. But happily, as proved to be the case in British Guiana, agricultural operations need not necessarily be favourable to the insect or to malaria; indeed, if properly conducted, they may be the most effectual way of eliminating the disease. In the Canal zone everything was in favour of the mosquito, and no agricultural operations presented themselves to the study of the Sanitary Department; so this great truth had not been realized; whereas in the Federated Malay States the opening up of land had been like a great experiment specially designed to show the importance of agriculture in the prevention of malaria. In discussing this with Dr Darling one day, I was told by him that from time to time he had had an opportunity of examining villages outside the Canal zone, and he kindly gave me the following memorandum:

[1] Jennings, "Some Problems of Mosquito Control in the Tropics," *Journal of Economic Entomology*, 1912.

BOARD OF HEALTH LABORATORY, ANCON, 31ST MAY, 1913

Memorandum for Dr Malcolm Watson: Blood Examinations for Malaria in Children at Native Villages in the Republic of Panama.

La Chorrera, 23rd August, 1910 Eighteen persons examined; three positive for malaria. *Anopheles albimanus* abundant in the village.

Chame Sixteen children examined; six positive. The only children having enlarged spleens in this series were two that were also infected with parasites. *Anopheles albimanus* breeding in the village.

Guarare, 25th October, 1910 Ten children examined; blood negative. No *Anopheles*[1] detected in the village, and no larvae found in few pools outside of the village.

La Ville de Los Santos Eleven children examined; all negative for parasites. At Los Santos thirty-four boys were examined for splenic index, and two had enlarged spleens.

(Signed) S. T. Darling.

At one of the places where there was little malaria, I have forgotten which, Dr Darling had been greatly impressed by the prosperity and the activity of the inhabitants. In the general appearance of the village, and in their business enterprise, the inhabitants presented a strong contrast to the ordinary Panamanian. Beyond these, Dr Darling had not had any opportunity of making observations outside of his ordinary work, and the relationship of agriculture to malaria had not been specially studied.

12.3.3 Other *Anopheles* species. Of these it is not necessary to say very much, for they have little or nothing to do with malaria. The following is taken from Mr Jenning's paper:[2]

A. argyritarsis is less common than *A. albimanus*, and although widely distributed, its numbers are never very great, and it is not very frequently found in buildings.

It is the only species of isthmian *Anopheles* which breeds readily in artificial containers. In ground-water it prefers the smaller collections. … It seems quite dependent upon the presence of algae.

A. pseudopunctipennis occurs abundantly from ocean to ocean, but is somewhat more discriminating than *A. albimanus* in choice of breeding places. It prefers as a rule water of greater purity and rapidity of current. The larval food, like that of *A. albimanus*, is by preference the soft green algae, though it does not scorn, lacking better, many places departing widely from the chosen type. At times its abundance is enormous, though usually far fewer of this species will find their way into buildings than is the case with *A. albimanus*, and its flight is less vigorous. Darling's experiments (see Chapter 14) show it is less easily infected with malaria than *A. albimanus*, and probably it is not a carrier in nature.

A. malefactor is widely distributed, and abundant. It is a large handsome species, a vigorous biter, active in entering houses. Yet apparently it does not transmit malaria. Its favourite breeding place seems to be, from what I saw and was told, large and deep shady pools.

[1] A dummy footnote [2] Jennings (see footnote on page 136, above.)

A. eiseni is a[1]

> strictly sylvan species, and breeds in depressions in the rocky beds of mountain streams, where protection from the rapidly flowing current is afforded, also in tree-holes and bamboo stumps. It is fairly abundant in favourable localities; yet I have never observed adults of the species at large by day, even in the dim light of the dense forest, nor at night when camping in the vicinity of active breeding places. I have no record of its entrance into buildings, and have never taken the larvae even a few yards beyond the edge of the forest. The relation of *A. eiseni* to malaria is not known, as it has been impossible to collect and breed sufficient material with which to work.

A. cruzi is[2]

> remarkable for its habit of breeding only in water held in the leaf-axils of various species of epiphytic bromeliads. … Like the last, this species is not observed free in the adult state, even when in camp near its breedingplaces.

In Panama, as in the Federated Malay States, we find each species of *Anopheles* with a preference for a special kind of breeding place, and each with habits so definite that anyone devoting some attention to the subject can easily learn them; so that when he goes over a piece of land and sees a stream or pool, he has a very good idea what its mosquito inhabitant is. It is true that on rare occasions larvae may be found in unusual breeding places. Mr Bath, divisional inspector, told me that only on two occasions in all his experience of the zone had he found *Anopheles albimanus* breeding elsewhere than in water on the ground: once larvae were found in water in the bottom of an abandoned French railway car or truck; on the other occasion they were in water in a clean kerosene tin. I think the explanation is very simple. With all other pools oiled, the mosquito was forced to lay her eggs on the only clean surface she could find. Accidents happen in the best regulated families; more than one human being has been born in a train.

12.3.4 On *Anopheles* adults. Of great interest are many of the observations made on adult mosquitoes on the zone.

In Havana it had been observed that *Aedes* (*Stegomyia*) *calopus* was a domestic mosquito, and practically never was found more than 200 yards from houses; and the scheme of mosquito destruction put into effect there, "though entirely directed against yellow fever, was almost equally successful against malaria."[3] The idea that the flight of *Anopheles* was also limited to this small distance was brought to the zone from Havana; and Colonel Gorgas, writing in July 1908, says:

> The inspector is required to keep the tropical undergrowth cut off within 200 yards of villages and 100 yards of isolated houses. Within this area the grass must be kept less than a foot high. I consider this scarcely less important than drainage. Bush and grass shelter the adult mosquito, and they will reach a habitation from distant breeding places by short flight if they have the continuous protection of bush, whereas the *Anopheles* will not cross a cleared area of 100 yards.

[1] Jennings (see footnote on page 136, above.) [2] *Ibid.* [3] "Report on the Isthmian Canal," by W. C. Gorgas. Article for *Engineering Record*, New York City, mailed 25th May 1904.

As time went on and the anti-mosquito work became so nearly perfect that mosquitoes were rarely seen by the ordinary inhabitant of the zone, and in a week only two or three hundred would be captured by the trained mosquito catchers in a large station, a condition was produced that presented unparalleled opportunities for observations on the flight of mosquitoes; and these, I need hardly say, were eagerly seized upon by the Sanitary Department. It is obvious that, if in ordinary times a place is practically free from mosquitoes, and the few that enter the area are captured and counted, any increase of the insect immigrants will be noted at once; and so it was in Panama. Immigration on a large scale has occurred on different occasions, and search having been made for the breeding places, the flight of the mosquitoes was found to be much greater than had generally been supposed.

12.3.5 Flights at Gatun. The first great flight, or immigration of *Anopheles*, occurred in 1911, and was caused by a hydraulic fill on the east side of the Canal to the north of Gatun. The photograph in Figure 10.6 shows the final condition of the fill, when the swamp had become solid dry land free from sun-cracks. At one stage, and in one part of this fill, extensive sun-cracks had developed in the mud, and in the water in the cracks enormous numbers of mosquitoes were produced.

The second great flight occurred at Gatun in 1913, again as the result of a hydraulic fill. On this occasion the larvae came, not from water in cracks in sun-dried mud, but from the portion of the swamp where the salt water of the "fill" was killing out freshwater jungle. In the sun-cracks there was probably some special food for the mosquitoes, of which, however, I do not think mention was made; and there would certainly be great security from such enemies as fish. The attraction in 1913 was, of course, the dead wood; and with abundant food and a certain amount of cover, the mosquitoes seemed to take little harm from the fish, which swarmed in the swamp. As the subject is of great importance, and is well told in the reports of the Sanitary Department for the months of January and February 1913, I cannot do better than reproduce these in full.

FROM THE REPORT FOR THE MONTH OF JANUARY 1913

Some very interesting data have been collected in reference to the increase of adult mosquitoes at Gatun, which was mentioned in the December report.

The weather conditions on the Atlantic slope and at Gatun have been somewhat different from those of recent years, and toward the end of the month several showers occurred at a time when continuous dry weather is usually expected.

As the number of *Anopheles* increased until the number of adults in and about residences in Gatun was very much larger than had ever occurred previously, it appeared that the origin of the sudden influx must have been caused by some new condition that did not exist in other dry seasons. It was evident that such condition must be due to topographical or other changes made since the previous dry season. The prominent changes made during the past year were four in number, viz.:

(1) The rise of water level in Gatun Lake to elevation Plus 55, followed by a collection of vegetable debris along the shore, and the rapid collection and growth of aquatic vegetation along the shore. Green algae did not occur there.

(2) A hydraulic fill north-east of the town was completed and brackish surface water only partially drained off, leaving but little dead vegetation near the surface.

(3) The natural drainage of an area north of bridge No. 9, between the old and new Panama railroad locations, had been affected by the silting of ditches in adjacent territory.

(4) A large fresh-water swamp, west of the French Canal, was being filled by hydraulic dredge, the water used for carrying the mud from present Canal channel being sea-water.

All of these areas were beyond the limits of where *Anopheles* control had been found to be essential in previous years.

In order to determine the source of the unusual *Anopheles* influx, all previously controlled areas were very carefully inspected and found to be in a satisfactory condition.

The four areas already mentioned were then examined in the order given above.

An examination of water in debris along the lake shore showed a few scattered *Culex* larvae and very few *Anopheles* larvae. The numerous small fish present were keeping down the number of *Culex* larvae, but it is thought possible that in time conditions will not be so favourable for the good control now accomplished by the fish.

An examination in the high vegetation on dry land along shore showed relatively few adult *Anopheles* in daytime and quite a few Culicines. The latter did not follow the observers out into the full sunlight.

Examination made by boat at night along the outer line of aquatic growth, within 50 feet or less from shore, showed an absence of adult *Anopheles*. This same state of affairs occurred near the shore at a point less than 300 feet from a row of labourers' cars, where over one hundred adult *Anopheles* were collected early each morning from each car. Moreover, no adult *Anopheles* were found in shade of brush near the cars in the daytime. The lake was, therefore, temporarily discarded as the possible source of supply.

The second area, the hydraulic fill north-east of the town, proved to be sterile as a production area, although some of the native huts not far away contained large numbers of ungorged female adult *Anopheles* in the daytime. This area extends from about 6000 to 10,000 feet from the Gatun railroad depot near the lake. It was temporarily discarded as having been a previous important source of the adult *Anopheles*, sufficient to account for the quantity present at the time the observations were made.

Third, the area north of bridge No. 9, extending from about 6000 to 10,000 feet north of the concrete railroad depot, which had been wet, dried up completely while the investigation was being made, and as at the time the *Anopheles* influx was still increasing rapidly it evidently should not be considered.

The remaining area, west of the French Canal, was next taken up. The inspection thereof was started at its western boundary, about 5000 feet from the railroad depot. The water there was fresh swamp water with no taste of salt. *Anopheles* adults were quite numerous. Plenty of water was present, and some places looked favourable, but no mosquito larvae were noted. The north-east end of the swamp was visited next, and water there was fresh. Adult *Anopheles* were very numerous, but no larvae present in water at that point. Adult *Anopheles albimanus* was present on nearly all tree trunks near the ground, and in all other suitable resting places.

It was decided to start from this point about 4500 feet from railroad depot, and to wade through the swamp in a general north-westerly direction. At about 200 yards from

shore, in water about 18 inches deep and thickly overgrown with bunch grass, we noted young *Anopheles* larvae. The water near by was just perceptibly brackish. It was noted that the *Anopheles* larvae increased as the water became more salty. In the wet area that was decidedly brackish, *Anopheles* larvae and pupae in all stages of development were noted. It is safe to state that they were more numerous than in any of the places in the Canal zone that have been encountered since 1904.

During the eight years of sanitary work on the zone only one case was recorded where *Anopheles* have bitten a person standing in the full rays of the sun. That occurred at 8 a.m. At the breeding place above mentioned this rule did not hold good, the *A. albimanus* and *A. tarsimaculatus* bit quite freely there in the full sunlight at all hours of the day. It is of interest to note that the larvae were so numerous as to be quite close together. More than twenty-four were noted on one plant leaf 6 inches long. The places where the larvae and pupae were most numerous contained from 30 to 75 percent of sea-water. *Culex* larvae were relatively scarce.

In the fringe of brush about 300 feet wide, on dry land between the edge of the swamp and the French Canal, *Anopheles* adults were very numerous in the daytime, and at night it was impossible for observers to remain there without being bitten quite frequently during a period of one minute.

The eastern edge of the swamp is approximately parallel with the present Panama railroad, located about 3000 feet west of it. The larger part of the settlement at Gatun is east of the Panama railroad, and some portions more than 6000 feet from the infected swamp and about east thereof. The prevailing winds blow from north to south, and hardly ever from west to east or east to west. There were many more millions of *Anopheles* coming from the swamp than were necessary to account for the influx at the houses east of the railroad track and more than a mile from the swamp.

It was necessary to determine at once whether this area was the source of the influx at the settlement. A rowboat containing several men known to be attractive to *Anopheles albimanus* was rowed very slowly up and down the French Canal each night for several nights. The *Anopheles* that came aboard were few in number, and not sufficient to account for the large influx at the settlement a mile distant.

It was assumed that such a large number of adults as would be produced every twenty-four hours at the production area must of necessity spread out or travel a considerable distance in order to get blood sufficient to satisfy them. It was thought within the limits of possibility that they might fly high and not be noted by persons in a boat. It was also assumed that the period of the long flight might be of limited duration. Other factors bearing on the question and previous results noted by specially trained and competent sanitary inspectors of the Canal zone in connection with the study of habits of malaria-conveying species of *Anopheles* were given due consideration. It was considered necessary to make several more thorough observations lasting over twenty-four hour periods before drawing any conclusions.

On 20th January, at 4.30 p.m., observers were posted on the opposite side of the French Canal from the propagation area and faced the latter, to observe any marked flight that might occur. Previously to 6.20 p.m. practically no mosquitoes were noted. At that time birds of the kind that feed on flying insects in the air, appeared to be very active, and were apparently feeding on insects in the air at an elevation of thirty or more feet above the water surface. Later, the birds operated at a lower elevation, and about 6.30 p.m. were feeding at about 6 feet or less above the water surface. It was at this time that the observers

on the bank and in the boat noticed the first appearance of *Anopheles*. The flight was from west to east, and quite marked. As it became darker the quantity of flying *Anopheles* increased, and by looking past a dark object against the clear sky hundreds of *Anopheles* could be seen passing by. These observations were continued for four consecutive nights, and the time of the start of the flight period remained about the same. After dark the flight was markedly reduced, and practically stopped completely before 9 p.m. Also, observers on the east, short of the French Canal, were attacked continuously during the period of flight, but failed to find a single *Anopheles* at 9 p.m., although they were very numerous on the west shore near the propagation area.

It would appear, then, that the *Anopheles albimanus* and *A. tarsimaculata* in the area mentioned ovideposit in water that is decidedly brackish, and that the adults fly eastward for long distances between six and eight o'clock. There is relatively little travel after that hour. Adult *Anopheles* were stained with dye and liberated at the swamp. Subsequently some of them were collected on the opposite side of the river, at the locks and in houses 4700 feet from the liberating station. It should be stated that the *Anopheles*' flight was decidedly marked and was easily noted by half a dozen witnesses, when their attention had been drawn to it. Even so, not one person in areas thickly infested did note the flight until shown the way to observe it.

It is very interesting to note that there is apparently no large or marked return flight to the swamp from east to west. It may be that such occurs, but that it is of a different nature from the direct flight and not yet understood. The most surprising part of the observations made was that the flight did not extend very far beyond the inhabited area where the employees live. It was expected that, with thousands of *Anopheles* adults travelling from the swamp to the settlement each night, some would go well beyond the settlement in the apparently direct line of flight. Such extension did not occur.

As the number of *Anopheles* occurring in houses and barracks increased rapidly, more *Anopheles* traps were installed, and eight labourers were employed exclusively for destroying mosquitoes in the barracks. Previous to the influx, there were relatively few cases of malaria or *Anopheles* at Gatun.

The combinations of such conditions with the work of the mosquito catchers and use of traps has prevented to a large extent the expected increase of the sick-rate at Gatun, as shown by the following figures: [see Table 12.3][1]

Apparently, up to date, millions of adult *Anopheles* have recently occurred near the settlements at Gatun, but due to the control methods used there has been no perceptible increase of malaria fever.

The sequel is told in the February Report:

In the report for January, data were given concerning the presence of adult *Anopheles* at Gatun. Two large ditches were made to drain the production area referred to, and it is now under control. The number of adult *Anopheles* in the settled area has decreased. Toward the end of the present month the prevailing species near the settlement was *Anopheles tarsimaculata*. Very few were noted in the office buildings in the daytime, even though a considerable number were resting in cracks in the ground under such buildings, and would bite quite freely there. It should be explained that the buildings are raised several feet or more above the ground surface. No *Anopheles* were found resting in shaded places

[1] The numbers that were given in this report are a subset of those contained in the subsequent report for February, which are shown in Table 12.3. (M. P.)

Table 12.3 Malaria incidence in Gatun during a major invasion of *Anopheles*. The statistics (which begin with October 1912) are taken from the Sanitary Department Report for February 1913.

Week ending		Number of adult *Anopheles* destroyed in houses	Percentage of employees sick with malaria
October	19	207	.27
	26	149	.35
November	2	199	.45
	9	404	.25
	16	666	.68
	23	779	.68
	30	3,397	.61
December	7	3,150	1.01
	14	3,296	.61
	21	5,430	.51
	28	9,415	.39
January	4	11,698	.50
	11	22,074	.41
	18	22,988	.55
	25	19,873	.62
February	1	15,746	.75
	8	15,580	.82
	15	15,676	.93
	22	11,441	.68
March	1	11,234	.54

on the under side of the floor system. Several stained *Anopheles* were found near the breeding area more than two weeks after they had been stained at that locality. It is of interest to note that some of the marked specimens were retaken more than 6000 feet from the point where they were liberated.

The work of destroying adult *Anopheles* in quarters at Gatun had been continued daily, with gratifying results. The table given below shows the increase of adult *Anopheles* at Gatun, and the corresponding malaria sick-rate. It indicates the value of such auxiliary control work: [See Table 12.3]

Extensive hydraulic fills are now being made on low lands between Diablo Hill, Balboa, and Panama. Observations show that the *Anopheles tarsimaculatus* and *A. albimanus* increase when salt water is introduced into the propagation area. That the number of larvae of these species is quite large even when the seawater content exceeds 60 percent, if other conditions are favourable. The areas being treated will have to be carefully watched and controlled temporarily to prevent *Anopheles* production. Ultimately the filled area will be non-productive, and will save the expense of anti-malaria work in future years.

Not least in interest is it to note that the malaria rate of Gatun did not increase. Whether this was entirely due to the mosquito catching or not, I am not prepared to say. It must not be forgotten that the population of Gatun had for many years been very free from malaria, and that the number of malarious people who could infect the *Anopheles* must have been smaller than in a place where a large number of *Anopheles* were continuously present throughout the year. The mosquitoes were the result of a condition so artificial that it could not remain permanently to produce these enormous numbers; and I think it would be unwise to argue that because mosquitoes have been known to fly over a mile in large numbers for a short period, measures to prevent malaria should be extended to a similar distance. I gathered that such occasional and temporary flights are not considered on the zone to be of any special danger, even if the mosquito catching were not carried out.

12.3.6 Flight at Miraflores. This occurred, as I have said, when the reservoir was being filled, and when abundant food in the form of dead timber was present in the water. The reservoir is situated about 4000 feet from the houses, and directly south from them. The prevailing wind being from north to south, the mosquitoes thus traveled against the wind for nearly a mile.

12.3.7 Flight at Corozal in 1912. At the beginning of the wet season in 1912, Corozal was invaded by an unusual number of *Anopheles*. They came from a mangrove swamp cut off from the sea by a bank, in which, as a result of the rainfall, the salinity of the water was less than usual. Whether or not this caused the death of some of the vegetation, I did not ascertain. Certainly it did not produce a complete destruction of the whole vegetation similar to that in the hydraulic fill at Gatun in 1913, of which there is a photograph in Figure 10.5, and it is unlikely that there were sun-cracks. Whatever was the cause, the effect was a great flight of *Anopheles*. Three weeks later the malaria rate of the station rose sharply from i percent to 2 percent and a month later to nearly 3 percent per week. The great influx lasted about two months, when it came to something about treble the normal rate, and remained so from the middle of July to the middle of November, when there was again a sharp increase.

At Corozal the violent fluctuations of the *Anopheles* catch and the malaria rate are much less directly connected than one would imagine, and raise the problem of how much of the malaria which occurs on the zone in the wet season is the result of the labourers getting chilled and suffering from relapses of old infections; how much is from new infections produced by the increased number of *Anopheles*, and how much is due to relapses among the many new arrivals who come from the West Indian Islands, many of which are highly malarious.

I do not propose to discuss this, for it is practically certain now that the annual rise is mainly from relapses among people who have imported their malaria. Year by year it has been getting less, until in 1913, for the first time, there was no increase during the wet season; and it is significant that in his report for 1912 the Quartermaster says 941 men were recruited from the small islands adjacent to Barbados, and adds, “This undoubtedly marks the last shipment of unskilled labour to the Canal.” It is more than

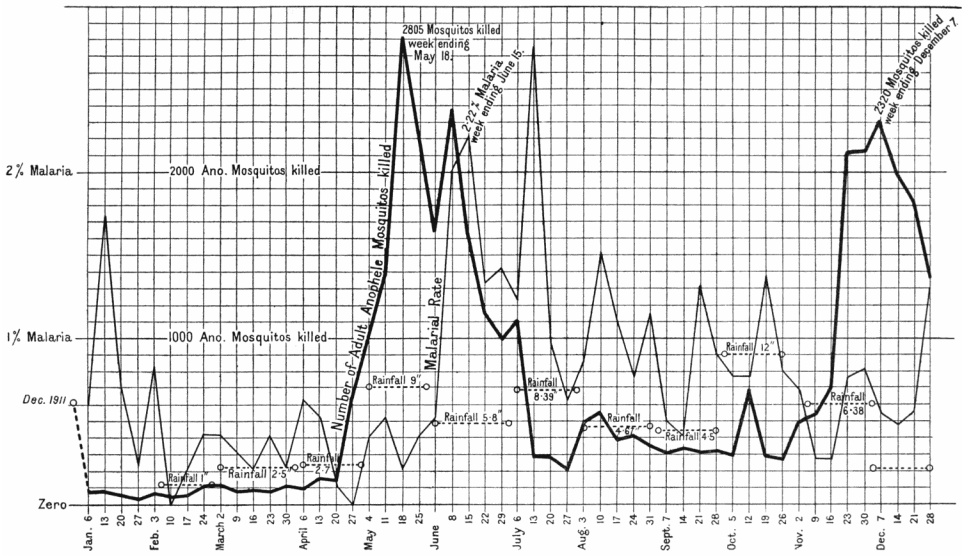


Figure 12.1 Chart of the malaria rate and the mosquito catch at Corozal

a coincidence that in the year after the stoppage of recruiting the annual malaria wave should disappear; and this taken with the fact that the population of the zone had reached the highest point yet attained, shows conclusively the origin of most of the relapses.

12.3.8 The effect of wind on, and the diffusion of, mosquitoes. Strong winds drive mosquitoes to cover; but where the air current is slight, mosquitoes have been observed on repeated occasions to fly or swarm head to the wind.[1] Great migrations of mosquitoes from salt marshes have been carefully investigated by Dr John B. Smith, of New Jersey, who has no hesitation "in stating that these salt marsh species may migrate inland for forty miles." The salt marsh mosquitoes, however, immigrate, possibly aided by the wind, but as more recent evidence shows, more probably flying into the wind.[2]

On the Canal zone it is apparent that whatever it is that attracts mosquitoes, they can and do travel against air currents of at least 5 miles an hour; and that more mosquitoes are found to windward of a swamp than to leeward. Mr Le Prince discusses this in a recent paper.[3] On the zone the prevailing wind is from north to south, and "it was noted that Anophelines were not as numerous at the labourers' camp at Ancon as at other stations, although there was a large swampy area to the north of it that contained Anopheline larvae." At Corozal, 3 miles north of Ancon, there was a swamp immediately to the north of the camp, and another to the south, "a little over a mile distant. … During the dry season of 1911 there were no *Anopheles* production areas within one mile to the south of Corozal, and anti-malarial operations were concentrated at the swamp

[1] *The Mosquitoes of North and Central America and the West Indies*, by Howard, Dyer, and Knab, p. 121.
[2] *Ibid.*, p. 339 and 341. [3] "Recent Progress in Anti-malarial Work, with special reference to *Anopheles*' Flight, as studied on the Isthmus of Panama," by J. A. Le Prince, *Trans. XVth Intern. Congr. on Hygiene and Demography*, Washington, D.C., September 1912.

to the north. In spite of the work done, many thousand Anophelines appeared each week at Corozal, and from one to two thousand were caught in one building. As the result of the work on the windward side was a failure, an extra brigade of labourers and oilers was put to work in the swamp more than a mile to the south of Corozal (to the leeward). As soon as that area was under control, the Anophelines at Corozal practically disappeared."

As an experiment oiling was then stopped in the swamp to windward at a distance of 2500 feet, but although "millions of Anophelines' larvae and pupae soon appeared, the number of adult Anophelines that reached the camp at Corozal decreased. It seemed quite evident that there was very little flight in the direction of the wind towards Corozal. During November 1911, when the wind blew from south to north, the Anopheline catch at Corozal at once increased." Observations confirming these were made at Miraflores, the station on the north of Corozal; so there seems little doubt that, like a bird in the wind and a fish in a stream, a mosquito is most comfortable when heading the current, and that it prefers to travel against the current when moderate in force. The practical point is, of course, that if we could depend on the wind blowing always in one direction, we should make the centre of the sanitary mosquito-free area not coincident with the centre of the settlement, but to leeward of it.

12.3.9 Mosquito traps. Many years ago, someone suggested that mosquitoes might be trapped in boxes painted black inside; the theory being that in the morning the mosquitoes in a house would retire to rest in a dark box. The lid of the box was then to be closed suddenly; a few drops of chloroform were next to be dropped into it through a small hole, and when stupefied, mosquitoes were to be taken out and burned. Of course this is not sanitation; nor would it produce enough excitement in the dullest spot to warrant a gamble on the catch.

But in Panama, Mr Bath, one of the two divisional inspectors, invented a trap of much Interest. It is made in three pieces, which can be taken apart, and is on the principle of a fish trap. The bottom piece of the trap is prism-shaped; the base is open; the two sides lead up to the apex, where there is a narrow slit, through which the mosquito readily enters, and from which it rarely escapes. Passing through another bottom with a similar slit, the mosquito is securely inside the trap. The trap can be fastened to any part of a house, with the opening either out or in, and it gives some idea of the number of mosquitoes which try to enter or leave the house. It may be left for a month, if the catches are small; but it is unwise to leave it longer, for spiders may close it up with their webs.

During the great flight of mosquitoes at Miraflores, one trap caught 1018 mosquitoes between 6 a.m. and 7 a.m. In sixty days an average of seven traps caught 37,268 *Anopheles*, and in addition many *Culex*. In forty-four traps the catch averaged from 90 to no mosquitoes for the individual traps, and 96 for the whole number. On another occasion eight traps were exposed for six nights, and it was discovered that the maximum flight was from 9 p.m. to midnight. The actual figures are given in Table 12.4. The wind was blowing from four to seven miles an hour. These figures are of interest, because they are not in accordance with what was observed in the Gatun flights in 1913.

Table 12.4 Mosquito traps: number of catches vs. times of day. Cumulative numbers of *Anopheles* mosquitoes caught at different times of day, using eight traps for a period of six days.

Time of day	Catches
6 to 9 p.m.	51
9 p.m. to midnight	270
midnight to 3 a.m.	89
3 to 6 a.m.	133

A point of practical importance has been demonstrated by these traps; it is that, to screen a house without giving special care to the part next to the eaves, is to court failure; for the largest catches have been got when the trap was just under the eaves. This is probably because all the mosquitoes which seek to enter the house, gradually work their way up the screening to the eaves, and there move along, constantly trying to get in. A trap in such a position would, therefore, get a large proportion of the mosquitoes which had tried to get into any portion of that side of the house. I have often heard people argue that as mosquitoes do not fly far from the ground, it is unnecessary to screen between the wall plate and the ceiling. In one hospital in the Federated Malay States this space was actually left open, although the rest of the hospital was screened. Needless to say the hospital became a mosquito trap, and, since then, mosquito-proof buildings have been consistently condemned by some people in the Federated Malay States as worse than useless. The largest catches were always got under the eaves on the lee side of a house, showing again that mosquitoes travel against the wind, and are not blown away by it.

Mr Bath has also found that mosquitoes rarely enter an unoccupied house. Unoccupied huts have been observed for some time; no mosquitoes have been found in them. Then men have been put to sleep in them for a few nights, when mosquitoes immediately appeared and could be caught. Lights do not attract mosquitoes, possibly smell does. The next largest catches are got at holes in the floor.

Mr Bath has patented his trap.

To test the direction of the flight of mosquitoes a simple apparatus was devised; it consists of two pieces of wood at right angles to each other, mounted on a pole 42 ft. from the ground, much like a signpost at crossroads. The surface of the cross-pieces is coated with a mixture something like bird lime, and any insect which alights on it cannot escape. The side on which the largest number of insects is found faces the direction from which the mosquitoes are coming.

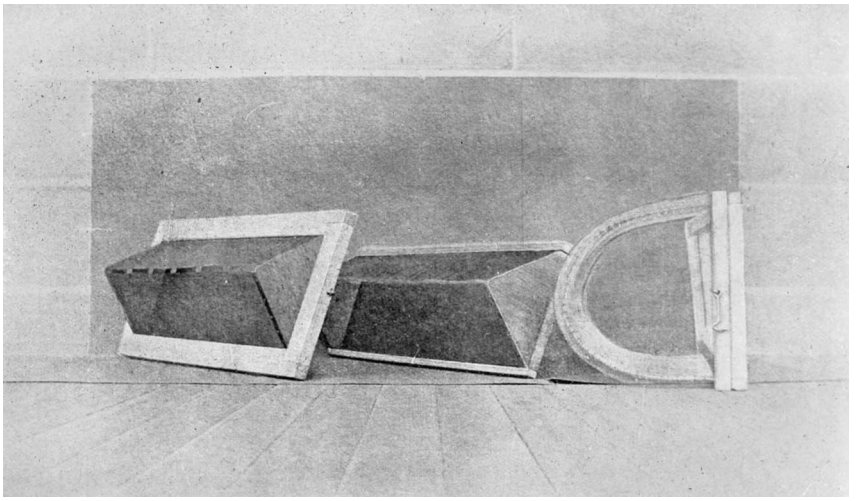


Figure 12.2 Mr Bath's mosquito trap

13. Panama: sanitary inspection reports; logistics

13.1 The weekly and monthly inspection reports

I have tried in the foregoing pages to show the nature of the work done by the Department of Sanitation in order to control disease; I now wish to speak of reports and inspections which enable the head of the Department and others to estimate the sanitary condition of the zone from week to week and from month to month. As the disease of most consequence, malaria comes first, and each week there is compiled "The Weekly Report of Malaria." It is the duty of each sanitary inspector to keep up to date the chart of the amount of malaria in each station, and the materials for this chart are carefully compiled by the district physician. Below reproduce an example in full (see Section A.3.1).[1]

All the weekly reports are sent to the office of the chief sanitary officer, and in a slightly condensed form a return of the employees of the whole of the stations is sent to each sanitary inspector. In this way each inspector sees the result obtained in other stations, and is encouraged to make his best efforts. In the actual form in which it was issued, I reproduce that for the week ending 5th July 1913 (see Section A.3.2).

In one respect only is the weekly report incomplete. It deals only with employees living in defined localities in the Canal zone, and takes no account of employees living in the cities of Panama or Colon, nor of those who live outside of the defined settlements in the jungle. There are a large number thus excluded from the weekly statistics; but while they may not appear in the weekly malaria report, all admissions to hospital and all deaths on the zone and cities appear in the monthly and annual statistics. The reason for the omission from the weekly reports above referred to is the impossibility of obtaining accurate figures each week of the number of people who live outside the defined areas.

13.2 Monthly report of sanitary inspections

It is not necessary to say much on this subject, because the form of the report which I now give [see Section A.3.3] is a sufficient indication of the care which must be given, and as a matter of fact is given, to the work. In what excellent order the screening is kept may be judged from what I have written; and all the work appeared to me on the same level.

[1] Facsimiles of the reports appear in the running text of the original edition, but they have been moved to the appendix in this one.

Table 13.1 Impounded water supplies in the Canal zone

Impounded area	Built	Elevation	Capacity (million gallons)	District supplied
Cocoli Lake	1909	36	429	Culebra to Panama
Rio Grande	1906	240	487	”
Camacho	1907	370	375	Empire
Carabali	1906	76	160	Gorgona
Agua Clara	1910	68	600	Gatun
Brazos Brook	1906	48	600	Cristobal, Colon

The district physician also has various reports to make, and from him comes a special report on kitchens, as follows [see Section A.3.4.]

13.3 Water supplies

I have already mentioned something about the water supplies of the zone, in connection with my visit to Gatun, Gorgona, and Empire; but it may be convenient if I give this subject further attention here. For much of the information, I am indebted to a paper[1] by Mr John R. Downes, physiologist, who is in charge of the water supplies. From this paper we learn that the water-supplies are obtained from various small impounded streams:

> A few places are supplied directly from the Chagres River or smaller streams, but these towns are also furnished with condensed water for drinking purposes.
>
> The impounded supplies are [listed in Table 13.1]. The watersheds and catchment areas have been depopulated and are patrolled by police. A watchman is in charge of each reservoir to prevent trespassing. In addition to these precautions, chemical, bacteriological, and microscopical examinations are made monthly. Small gangs of men keep down all vegetation for a distance of from 50 to 150 feet from high water.
>
> In 1906 and 1907, two 1,500,000-gallon New York Continental pressure filters were installed; one at Ancon, to filter the Rio Grande supply for Ancon and Panama, and the other at Mount Hope, to filter the Brazos supply for Cristobal and Colon. From a bacteriological standpoint, these filters are not required. They, however, serve to remove the iron-organic matter from the waters, greatly improving their appearance and palatability.
>
> The Ancon plant worked well when set up in the standard way. The Mount Hope plant could not carry the load imposed by the heavy iron-organic content of the Brazos water, and the filters were plugged to a standstill inside of two hours.
>
> I recommended the use of preliminary coagulation and sedimentation. A basin of 400,000 gallons capacity was accordingly built. … The water on entering the basin is dosed with sulphate of alumina, which flows by gravity from the solution storage tanks. The bulk of the precipitate is obtained in the first three sections of the basin. In all about 90 percent of the flock and impurities are removed by the basin, and the filters can then handle the water easily.

[1] “A Study of the Water Supplies of the Isthmus of Panama,” by J. R. Downes, *Proc. Canal Zone Med. Assoc.*, April to Sept. 1910.

This plant has since then been much enlarged.

> I will state that in general all these waters are soft, being practically rainwater. They have, however, taken up a large amount of organic matter, which at times causes a disagreeable appearance and taste. The worst that can be said of them from a sanitary standpoint is that, when present, this disagreeable appearance and taste prevent the drinking of sufficient quantities of water.
>
> Each reservoir has an individuality which must be considered. Brazos Brook is characterized by water of high colour, and high iron content, which gives it a very disagreeable appearance, as well as a disagreeable, brassy taste at times. No algae of any importance ever occur in this reservoir.
>
> Carabali Reservoir at Gorgona is characterised by its adaptability for alga growth, especially of the obnoxious *Anabaena*. The water is clear and of good appearance and taste when these growths are not present. This is the only reservoir giving much trouble from this cause. Camacho Reservoir at Empire gives the least trouble of any from all causes. Rio Grande is noted particularly for the foul odours which it produces at times. These odours have never been traced to alga growths, but, as in the case of Brazos Brook, are due to chemical or bacteriological changes which take place in the lower strata of water where there is no oxygen. … Time and again complaints of foul odours in the waters have been followed up, and the trouble always located in the stagnation of the lower strata of water. … The trouble occurs equally in periods of heavy rain and when it is dry; and also in the change from the dry to the rainy season, and from the rainy to the dry. Invariably the trouble is the same: i.e. lack of oxygen in the lower strata from which the water is being drawn. The points at which the oxygen shows rapid diminution are always marked by an abrupt drop in the temperature of the water, which accounts readily for the stratification.

I cannot follow all the points of this most interesting paper; it deals with technique for dissolved oxygen work, as well as with the bacteriology of the supplies. Perhaps I have over-emphasised that part of the paper which deals with the unpleasant taste of the water; but I have specially referred to it because it is a real difficulty in connection with the Panama supplies which has not yet been overcome, and it is one which might at any time present itself to the sanitarian in the tropics. But if the experience of typhoid fever is to be taken as a test of the purity of the water supplies and of the state of general sanitation in the zone, then the typhoid death rate of 13.3 per 100,000 in 1909 will compare favourably with that of most cities in or out of the tropics.

13.4 Sewage System

Of this I know practically nothing, except that it is a separate system, no rainwater gaining an entrance to the sewers. Such sewers as I saw were the smaller ones, and consisted of glazed earthenware pipes.

For many years English sanitarians in the tropics have hesitated to lay down a system of water-carried sewage; chiefly because it was feared that Asiatics would so abuse it that the sewers would become blocked; and to a less degree, because, from the water-seals of the traps becoming lost through evaporation, foul gases and rats would gain an entrance to houses. There can be little doubt the dangers of a sewer system have

been exaggerated; and that where the water supply is sufficiently abundant, it will be universally adopted in tropical towns in the next fifty years. It has been a success in Manila; and a system is now nearing completion in Singapore. In Panama I saw nothing to lead me to suspect there was any difficulty with the sewers; nor did inquiry discover that any existed. The sewer system is a part of the sanitary system which calls for no more attention than it does in a non-tropical country; and, since in Panama nine-tenths of the population consist of negroes, the best testimonial it can get is that one neither sees, smells, nor hears about it.

13.5 The Commissary and Subsistence Department

When the number of employees on the zone began to increase, the price of everything rose to an absurd height. To have allowed this to continue would have been simply to add to the difficulty of recruiting both whites and blacks; so a great system of stores was established, called the Commissary.

It has buyers in the United States; and as European goods can enter without paying duty to the Republic of Panama, many articles cost less than they do in the United States; such a thing as clothing is much cheaper on the zone. The articles bought range from the proverbial needle to the anchor; in fact, everything that is required for a household is to be found in the Commissary. The headquarters are at Cristobal, and from there a special train runs across the isthmus every morning taking supplies to the local commissaries along the line.

In addition to supplying people from the local commissaries or stores, the Subsistence Department operates a number of places where cooked meals can be obtained. These consisted, in 1912, of nineteen line hotels, such as the one I visited at Gatun, for whites; eighteen European labourers' messes; and eighteen common labourers' kitchens for negroes and others of that class; in addition there were three night restaurants. The Hotel Tivoli at Ancon, which has accommodation for 300 people, is also under the Subsistence Department. I lived in it during my stay on the zone, and found the management excellent. While this department is of the highest service to the residents of the zone in many ways, I have found that a good deal of misconception exists as to the feeding of the native labour force on the zone. By many it is supposed that the whole of the labour is supplied with cooked meals, which is very far from being the case. In the Annual Report I find the following: "The average daily attendance during June 1912, was 2682 at the line hotels, 2834 at the messes, and 1446 at the kitchens." From these figures it is clearly seen that under 3 percent of the labourers are supplied with cooked rations.

14. Panama: local malaria research

14.1 The Board of Health Laboratories

In a small, quite unpretentious building, Dr Darling carries on his multifarious duties and researches. I have already told how his laboratory devised the effective and relatively cheap larvicide which is so extensively used on the zone; I do not propose to dilate on the widespread usefulness of his laboratory, which examines anything from throat swabs for diphtheria to gear grease for engines. Fireclay and malignant tumours are equally sent for examination; while a considerable embalming business is carried on, for the bodies of all citizens of the United States who die on the zone are sent back to the place they came from. Apart from all this work, which, although routine, is of the highest value to the community, Dr Darling has found time to carry on research work on a number of important subjects. His discovery of the ease with which kittens can be infected with amoebic dysentery has gone far towards determining the relationship between the various bodies seen in a dysentery stool.[1] Nor, in view of the serious nature of sleeping sickness, is his paper on the immunization of animals against a trypanosome disease any less interesting.[2] Other papers deal with the oriental sore in Panama,[3] relapsing fever,[4] sarcosporidiosis,[5] and show what good use is made of the wealth of material which pours into the laboratory at Ancon.

Into a volume entitled *Studies in relation to Malaria*, published at Washington by the Government Printing Office (1910), Dr Darling has collected a series of valuable observations on:

- Anophelines of this region
- Collection of larvae
- Breeding out mosquitoes, and methods of feeding
- Biting—infecting experiments
- Estimation of gametes
- Care of mosquitoes after feeding
- Method of examining for zygotes and sporozoites

[1] "The Rectal Inoculations of Kittens as an aid in determining the Identity of Pathogenic Entamoebae," S. T. Darling, *Bulletin de la Societé de Pathologic Exotique," March 1913.* [2] "The Immunization of Large Animals to a Pathogenic Trypanosome *Trypanosoma hippicum*, Darling) by means of an Avirulent Strain," Journ. Exper. Med., 1913. [3] "Oriental Sore in Panama," Darling, *Proc. Canal Zone Med. Assoc., 1911.* [4] "The Relapsing Fever of Panama," Darling, *The Arch. of Internal Medicine*, August 1909. [5] "Sarcosporidiosis—with a report of a case in man," Darling, *The Arch. of Internal Medicine*, April 1909.

- Description of the malaria parasite in the mosquito
- Table of infecting experiments
- Motes and conclusions from table of infecting experiments
- Limit of infectiousness of man
- Notes on the bionomics of Anophelines
- Effect of salt or sea water on larvae
- Experiments with larvicides
- Experiments with agents destructive of vegetation grass, and algae
- Experiments with screening of various mesh
- Relative value of wire-screening of various composition, based on practical tests and chemical analyses
- Notes on the value of the practice of killing Anophelines found in quarters and barracks
- Latent malaria
- Effect of quinine upon the parasite in mosquito and man

I have already had occasion to quote from Dr Darling's researches on many of these points, so it is unnecessary to do more than mention them, but to several other points in this original paper I must refer.

14.2 Feeding Mosquitoes

All those who have attempted experimental work with mosquitoes know the difficulty there is in keeping the larvae, and especially the adults alive, in captivity. Dr Darling has ingeniously overcome some of these difficulties. He found that aerating the water with a "Pacquelin cautery bulb, having a heavy glass perforated tip," kept the water fresh, and the larvae usually hatched out. The tanks are aerated with the fine jets of air twice a day. Dr Darling also found that adult mosquitoes could be kept alive on dates and raisins, along with a little water, and that this food suited the insect better than the usual banana, which seemed to induce the growth of yeasts and fermentative acids in the mosquito's stomach, with fatal results.

Especially interesting were his experiments to determine how many of the gametes (male and female malaria parasites) failed to breed when taken up by the mosquito. To do this he weighed a number of mosquitoes before and after feeding, and determined that the average meal of blood weighed approximately 0.0008 gramme—its own weight in blood. He then counted the number of malaria parasites in a certain quantity of blood, and so determined the number the mosquito had sucked in. The experiment showed that no less than 97 percent of the parasites were lost—apparently another instance of the extreme prodigality of nature where sexual reproduction is concerned. And yet we need not be surprised at this in malaria, when we consider how few seeds ever become trees.

Table 14.1 Malaria-carrying *Anopheles* species. Results of infection experiments by Dr Darling.

Species	Number	Infected	% Infected
A. malefactor	17	–	–
A. pseudopunctipennis	31	4	12.9
A. albimanus	48	34	70.2
A. argyritarsis[1]	4	–	–
A. tarsimaculata	5	3	60.0

[1] A naturally infected specimen of this species has been found in barracks.

14.3 The malaria-carrying mosquitoes

After a series of experiments on mosquitoes, Dr Darling reached the conclusions that *A. albimanus* is the chief carrier of malaria on the zone. His results are shown in Table 14.1.

In view of the fact that the zygotes of malaria have been found in the stomach of such an *Anopheles* as *A. rossii*, this table cannot perhaps be taken as proving that *A. pseudopunctipennis* is a carrier of malaria when wild, and Dr Darling says it "is only slightly concerned in the transmission of malaria fever, if at all, not only from the fact that only four out of thirty-one mosquitoes under the most favourable artificial conditions became infected, but from the additional fact that relatively few specimens are taken in quarters at this time."

A. malefactor, which is "widely distributed and abundant locally … active in entering houses, and a vigorous biter,"[1] is shown by Dr Darling not to carry malaria. This is another warning not to assume an *Anopheles* is responsible for causing malaria in a place merely because it is abundant and freely feeds on man.

14.4 Human carriers of malaria

In March 1909 Dr Darling examined the blood of 269 Spanish labourers, part of whom lived at Ancon and part at Cucaracha. Twenty-nine, or fully 10 percent were found to have malaria in their blood. All the labourers had been at work, and were working every day. Later on two entered hospital with malaria, and it was noted that the two were not among those in whom malaria had been found. These labourers lived in screened houses. Among children and adults living in unscreened quarters the percentage infected was much higher; in one group four out of six, and in another six out of thirteen were infected. Dr Darling thus confirms what has been found in other countries, namely, that much malaria exists in a latent form during the period when people are acquiring immunity to the disease.

[1] "Some Problems on Mosquito Control in the Tropics," Jennings, *Journal of Economic Entomology*, 1912, p. 134.

Table 14.2 Annual admissions to hospitals and sick camps in the Canal zone

No. admitted	1907	1908	1909	1910	1911	1912	1913
To hospitals	32,063	27,251	27,154	32,239	34,196	32,129	30,993
To sick camps	32,451	27,528	18,102	19,991	18,296	12,333	1,208

14.5 Fish

I have already described how on many occasions I found fish in the same water as larvae; and I am by no means certain to what extent they destroy larvae under natural conditions. Laboratory experiments are quite useless; for, as Dr Darling told me, he had put larvae into vessels containing various kinds of fish, and on every occasion except one the larvae were eaten up in a few hours. In the single exception, all the fish died in twenty-four hours, so it is probable they were not healthy. Not only are fish destructive of larvae when in bottles, but so are almost all the aquatic insects, such as water-beetles and dragonfly larvae. Many and many a time I have lost all the larvae I had spent hours in collecting by overlooking a diminutive aquatic insect. Yet it is obvious, from the great number of these enemies which one finds in water containing larvae, that they cannot possibly be so destructive when at large as when in a bottle; presumably the larvae are then unable to take cover.

14.6 Treatment of the sick

The treatment of the sick is carried out under the supervision of Colonel Mason. Originally there were ten hospitals on the Canal zone; but as early as 1907 this number was reduced to two large ones, situated at Colon and Ancon; there is also a very small one at Culebra, mainly for non-employees. This, of course, raised the efficiency of the hospitals, and also lowered the cost. In addition to the hospitals there have always been sick camps. These do not differ from the quarters in which the labour force is housed. They do not pretend to be hospitals, nor are they elaborately equipped like the hospitals, and the cost of running them is only forty-four cents per capita per day, against $1.21 for hospitals (these are the figures for 1911). How important a part these simple sick camps have played in the zone will be gathered from a glance at Table 14.2, which shows the admissions during the years 1907 to 1913 to the hospitals and camps, respectively.

It is important to note this point, for a moment's consideration will show how greatly these sick camps must have reduced the total cost of treating the sick. In 1913 these camps were abolished, with the exception of a few at stations not on the railway, because the hospitals were, from the greatly diminished sick-rate on the zone, then able to accommodate all who could not be treated in their own homes or at the dispensaries. The year 1913 is distinguished as being that in which for the first time the Americans succeeded in completely abolishing the annual malarial wave, which is responsible for the filling of the hospitals at a certain period of the year.

In addition to the hospitals and sick camps, there are dispensaries under the district physicians. At these large numbers are treated. In 1912 there were 601,742 attendances. At the dispensaries the physician decides whether the patient is to be sent to hospital, to sick camp, or to be treated in his quarters—the local expression being "excused for quarters." Of the hospitals I do not propose to say much, except that they are among the best in the tropics; and, as far as the work done in them is concerned, will take second place to none, whether within or out of the tropics. Many of the buildings are a legacy from the French. At Ancon they are scattered all round the hill; at Colon they are also isolated pavilions, but there they are built over the sea on the coral rocks. Like other Commission buildings they are screened. The nursing staff for both whites and blacks is white.

Dr Herrick is in charge of the surgical side of the hospital; Dr Deeks, of the medical; Dr W. M. James in charge of the clinical laboratory. Many valuable papers have been published from the wards of Ancon hospital on malaria, dysentery, and other diseases of the tropics, but I single out the volume on *Haemoglobinuric Fever in the Canal Zone* as an illuminating contribution to one of the most obscure problems of tropical medicine. Here, as well as later on I shall quote extensively from it, for the author's words cannot be improved upon. It is based on a study of 224 cases, of whom 24 were Americans, 143 Europeans, 28 Barbadians, 23 West Indians, and 4 Panamanians, Chileans, or Mexicans.

After a most careful study of these cases, they arrive at certain conclusions which I give below; I would draw attention especially to No. 4. At this time when quinine has been dethroned from the high place upon which Koch placed it, there is a tendency among the public to fly to the opposite extreme and to say quinine is of no value. I am glad, therefore, that much emphasis has been placed on the neglect of quinine as a definite condition in the production of blackwater fever.

> There is no proof that blackwater fever has spread from one country to another, or from one part of a country to another, as have kala-azar, yellow fever, and sleeping sickness. On the contrary, the disease invariably manifests itself when certain conditions relative to the epidemiology of malaria, and to that of no other disease, are present. These conditions are:
>
> (1) The presence of a population non-immune to malaria.
>
> (2) The prevalence of malaria in such quantity as to produce an almost continuous infection in this population.
>
> (3) A large proportion of estivo-autumnal malaria, because the amount of blackwater fever is in direct proportion to the intensity of this variety.
>
> (4) The neglect of prompt and continuous administration of quinine, especially in primary attacks, to persons nonimmune to malaria. In every locality, without exception, where these conditions obtain haemoglobinuric fever is found …
>
> The primary cause in haemoglobinuric fever is either prior or coincident malaria, or both; the immediate cause is sometimes the administration of quinine, but this never acts unless the primary cause has been or is present. With this knowledge we are able to treat the syndrome intelligently, and often to prevent its occurrence by the removal of the primary cause, and by sending away from the source of infection those who, since

by reason of personal idiosyncrasy they cannot take quinine at any time without the production of blackwater fever, should not remain in a malarious country.

14.7 Canal Zone Medical Association

After dinner one evening, Dr Darling introduced me to the Canal Zone Medical Association, of which Dr W. M. James was president. The meeting was well attended, another strong evidence of the keenness of the medical men on the zone. Dr Deeks, chief of the Medical Clinic, Ancon Hospital, read a paper on the clinical diagnosis and post-mortem findings of the last 500 consecutive fatal cases from his wards. The paper was profoundly interesting. It dealt with the different groups of diseases; gave the percentage of correct diagnoses in each group, where partly correct and where wrong, and discussed the various pitfalls for the diagnostician.

Despite all difficulties, Dr Deeks could point to over 80 percent of successes; to a considerable percentage where the difference was more in the name than anything else, and in the balance a correct diagnosis would have given the patient no better chance of life even if it could have been possible to make it during life. The discussion which followed was most interesting; and not least so were some of the different opinions as to how death should be classified, when malaria parasites, found in the wards, had disappeared under treatment, while at the autopsy no parasites or anything very definite could be found. When asked to speak, I congratulated the author on his paper and on his work, and said it reminded me of how Sir W. T. Gairdner studied his fatal cases in the post-mortem room.

The great physician learns in the post-mortem room no less than in the ward, and his patients reap the benefit in more correct diagnosis and more appropriate treatment. In conclusion, I would add that the Canal Zone Medical Association publishes its proceedings, to some of which I shall have occasion to refer later. For a moment I will refer to the kind but embarrassing way in which I was welcomed to this society, and also to one in Washington. Immediately after the minutes were read, and under the heading of "General," the president referred in very kind terms to my presence, and asked me to tell them something about my work on malaria in Malaya. Luckily, my previous experience at Washington put me on my guard, and I produced a tabloid lecture on malaria lasting about ninety seconds. It was a kind welcome; but for those who are not aware of the custom, a somewhat embarrassing one, and I write this as a warning for any of my countrymen who have not yet visited the U.S.A.

15. Panama: results from sanitation

15.1 Lowering of the general death rate

Every month full details are published of the health of the Canal zone and of the cities of Colon and Panama, as well as statistics of the amount of sanitary work done; and the monthly reports are condensed into the annual reports, which are also published. From them it is possible to follow, from year to year, the improvement in the health of the inhabitants, and the success of the sanitary work. In addition to that in the reports, information can be obtained from many of the papers published by individual members of the Sanitary Department: and I am indebted to Colonel Phillips, acting chief sanitary officer, for certain other information hitherto unpublished.

Broadly, the results summarized in Table 15.1 bring out how for the first two and a half years of the American occupation the death rate increased along with the increase of the labour force; but that since 1906 there has been a steady improvement, and this although the labour force increased much more rapidly than in the previous period. This remarkable improvement is due to a reduction in the death rate from all diseases. In Table 15.2 the number of deaths from special diseases is not shown as a rate per thousand, but the actual number of deaths is given.

Not only have the employees on the zone benefited by the work of the Sanitary Department, but so have the cities of Panama. And Table 15.3 answers the question: Does Sanitation Pay? The answer is that it does pay in lives saved; but to consider the gain only from this point is to fail to realise that, but for the improved health, it would never have been possible to gather together, or keep together if gathered, the great labour force necessary for the construction of the Canal.

15.2 The labour problem in 1906

Some conception of how serious the labour problem was will be found in a report made by Colonel Goethals when he first took charge. The report is relative to giving the Canal work out on contract, and says:

> The Panama Canal presents a piece of work unprecedented in magnitude, which must be done under conditions entirely different from similar classes of work in the United States. The work naturally divides itself into dredging, dry excavation, the construction of the locks and dams, and the construction of the new Panama railroad. There is no contractor, or syndicate of contractors, that by any combination could bring to the Isthmus an organization ready for team work on any of these units. From the United States the

Table 15.1 death rates of employees in the Canal zone

Year	Number of employees	Deaths	death rate per 1000
1904	6,213	82	13.26
1905	16,512	427	25.86
1906	26,547	1,105	41.73
1907	39,238	1,131	28.74
1908	43,891	571	13.01
1909	47,167	502	10.64
1910	50,802	558	10.98
1911	48,876	539	11.02
1912	50,893	467	9,18
1913	56,654	473	8.35

Table 15.2 Number of deaths from major diseases among Canal zone employees, by year

Disease	1905	1906	1907	1908	1909	1910	1911	1912	1913
Typhoid fever	12	42	98	19	13	13	10	4	4
Dysentery	14	69	48	16	8	21	13	7	6
Pneumonia	95	413	328	93	70	73	94	57	47
Malaria	86	233	154	73	52	59	47	20	21

supply of labour is the same whether the work be done by contract or by the Government, and the character of the labour must be the same.

So long as work is plentiful, the dread of the tropics will deter men from seeking work here in preference, and this is equally applicable lo the contractor and the Government. An adequate supply of labour from the United States is not possible. The records here show that no contractor can even attempt to recruit labour in the West Indies, and that great opposition will develop to any recruiting by authorized agents of the Commission if the labour procured is turned over to the contractors. These island governments cannot be blamed for their hostility towards the latter, because of their experience under the French, which left an indelible impression throughout the islands.

Conditions on the Isthmus are peculiar. It is contended, apparently on reasonable grounds, that service in the tropics saps the energy, and that a man is incapable, after a time, of performing the same amount of work that he could be able to accomplish had he spent the same time in a cooler climate. This creates a desire to accumulate sufficient means to avoid the necessity of relatively harder work on the return to the United States, and it is a question that the contractor would be obliged to face, as well as the United States. The wage scale on the Isthmus is practically adopted, and a contractor would be obliged to maintain it.

Table 15.3 Overall outcomes of sanitary work in the Canal zone. The numbers of lives saved per year are calculated from the total population and the improvement in death rate over that recorded in 1904.

Year	Population	Death rate per 1000	Lives saved
1904	35,000	52.45	–
1905	56,624	49.94	142
1906	73,264	49.10	299
1907	102,133	33.63	1,922
1908	120,133	24.83	3,317
1909	135,180	18.19	4,631
1910	151,591	21.18	4,740
1911	156,936	21.46	4,683
1912	146,510	20.49	4,682
Total lives saved for eight years			24,596

> No account has been taken of the question of sanitation, one very important to the successful prosecution and completion of the work on the Canal. Proper sanitation can be maintained more easily and satisfactorily with the Government in supreme control of the work, than with the contractor. The relative advantages of the contract system versus hired labour under government supervision are very different today from what they were two years ago. To one familiar with conditions on the Isthmus there can be no doubt at this stage of the work as to the advisability of continuing it with hired labour.

Up to 30th June 1906 most of the labour on the Canal was drawn from the West Indian peoples, but as it was unsatisfactory from many points of view, labourers were brought from Spain. The Report of the Commission for 1906 says:

> Another year's experience from near-by tropical islands and countries has convinced the Commission of the impossibility of doing satisfactory work with them. Not only do they seem to be disqualified by lack of actual vitality, but their disposition to labour seems to be as frail as their bodily strength. Few of them are steady workers. The majority of them just work long enough to get money to supply their actual bodily necessities, with the result that while the Commission is quartering and caring for about 25,000 men, the daily effective force is many thousands less. Many of them settle in the jungle, building little shacks, raising enough to keep them alive, and working only a day or two occasionally, as they see fit. In this way, by getting away from the Commission's quarters, practical control over them is lost, and it becomes very difficult for foremen to calculate on keeping their gangs filled.
>
> The experiment with labourers from northern Spain has proved very satisfactory. Their efficiency is not only more than double that of the negroes, but they stand the climate much better. They have malaria in about the same degree as the white Americans, but not at all to the extent the negroes have it. Their general condition is about as good as it was at their homes in Spain. The chief engineer is convinced by this experiment that

> any white man so called under the same conditions will stand the climate on the Isthmus very much better than the negroes, who are supposed to be immune from practically everything, but who, as a matter of fact, are subject to almost everything.

Even in 1907 the Commission reports:

> The labour problem is still an unsolved one, but the experiment of the last year with a diversity of races and nationalities has improved the efficiency of the force and promises to make the term of service longer. Tropical labour is migratory, and notwithstanding superior wages, housing, and subsistence, there will always be large periodical changes in the individual force. A regular recruiting organization, changed from one labour centre to another, will always be necessary to keep a maximum force available.

15.3 The Composition of the Labour Force

By 1908 the problem had been solved. In two years the labour force had jumped from 26,000 to 43,000, and the death rate had fallen from 41 to 13 per 1000. From that time labour, as plentiful as the Americans could wish, has poured into the zone. Consisting of three different races who have shown different powers of resistance to disease, a detailed knowledge of the inhabitants of the zone and their habits is necessary for a full appreciation of the sanitary work. As this subject is very carefully considered by Drs Deeks and James in the report to which I previously alluded,[1] I cannot do better than extract in extenso from that report:

> **THE RACIAL DISTRIBUTION OF THE EMPLOYEES OF THE CANAL COMMISSION AND THEIR MANNER OF LIVING**
>
> Since the American occupation of the Canal zone, its inhabitants may be divided into two groups; the one composed of those who work for the Isthmian Canal Commission (referred to hereafter as the Commission), the other made up of natives of the country, with such immigrants as have been attracted by the increase in business. Upon the number and racial distribution of the persons included in the first group are based the data set forth subsequently. This group comprises three distinct races: the American, which is Anglo-Saxon in origin; the European made up mostly of Spanish and Italian labourers, with a considerable preponderance of Spaniards; and the West Indian negro, coming in greater part from the islands of Jamaica and Barbados. The numerical ratio between the two races, the time of residence in this country of the individuals who comprise them, and the relative susceptibility of each race to disease, must be kept constantly in mind, for these factors render complicated any attempt to compile reliable statistics that pertain to the total distribution of disease in this country. Two sets of figures are necessary, the one showing the total disease for all races, the other, totals for the separate races. And as far as possible such figures have been obtained. The second group, that of natives and non-employees, is of importance only in so far as it acts as a means of conveyance of disease to the first; the prevalence of disease in it does not affect to any appreciable extent the figures used in the subsequent tables and charts.
>
> These three races are natives of localities where, broadly speaking, malaria does not prevail to any great degree. The Italians are mostly from the north of Italy; the Spaniards

[1] *A Report on Haemoglobinuric Fever in the Canal Zone*, 1911.

from the north of Spain, and Jamaica is not badly infected with malaria, while Barbados is said to be free from endemic cases. Such immunity against malaria, as is present during the earlier part of a residence here, is therefore racial and not acquired. How much of such immunity exists will be shown later. It is sufficient at present to say that Americans and Europeans alike are susceptible to the disease, while the negro possesses a partial racial immunity.

The same general conditions of sanitation, such as drainage, water supplies, sites from which grass and under-brush are removed, and inspection of quarters by the Department of Sanitation, obtain equally among the three races. But it is impossible to equalise the racial appreciation of such important individual sanitary measures as care of screening, predisposition to cleanliness, prophylactic use of quinine, and personal regard for health. These latter vary greatly among the races, and are directly responsible for the prevalence of malaria in proportion to racial susceptibility to the disease.

The American employees of the Commission are skilled mechanics, clerks, foremen, responsible railroad employees, civil engineers, physicians, and nurses, and others who fill the many positions connected with the executive, constructive, and administrative functions of the Canal building. Since January 1906, almost without exception, they have lived in houses provided by the Commission. These houses are equipped with screen doors, screened windows and verandahs, and are well kept by their inhabitants, any defects in the screening or the plumbing being reported promptly. Among these employees the use of quinine at the first onset of fever is universal, and prompt consultation with the nearest Commission physician is the rule. Each employee is granted six weeks' vacation, with pay, for twelve months' service, and this vacation must be taken in the States or in a malaria-free country. If a bachelor is too ill to work, he is sent to the Commission hospital at Ancon or Colon, and most married men who, by reason of sickness, are unfit for duty, also avail themselves of the hospital service. A sanatorium for convalescent patients is maintained in the malaria-free island of Taboga, in the Gulf of Panama. The Americans do not frequent at night the native quarters in the zone towns; do not expose themselves unnecessarily to malaria infection, and of their own initiative aid greatly in preserving their health and in keeping sanitary regulations. Classed with Americans, who are also called "gold" employees, are those white men of other nationalities who hold positions entitling them to similar quarters and treatment.

Those of the European labourers who so desire live in well-kept and carefully screened barracks, and for families, screened quarters are provided. But no amount of advice seems to be effective in securing among them individual prophylaxis against disease. Every sanitary regulation needs to be rigidly enforced. They often prefer to sleep in hammocks or even on the ground under their quarters or in other places. They mingle freely at night with the natives, and cannot be kept indoors. As a race they are not addicted to strong liquor, but we are informed by Mr Le Prince, the chief sanitary inspector, than an increase in malaria among them is always accompanied by an excessive consumption of rum, and very inferior rum, in the belief that the drink is an efficient medicine. They are indifferent to personal hygiene, and equally indifferent to their state of health, until illness compels them to seek aid.

As elsewhere in the world, the enforcement of sanitation among the negroes is a gigantic task. A small percentage only of this race live in the free quarters provided by the Commission. The rest either prefer cheap lodging houses, where they huddle together at night like so many sheep, or else they live in straw-thatched huts after the manner of the

Table 15.4 Ethnic variation of mortality among employees. Annual death rates per 1000 Isthmian Canal Commission employees, broken down according to ethnic groups and major causes. For 1912, the grand total of the death rate was 9.54 per 1000 for coloured employees and 8.05 for white employees.

	Year	Injury	Malaria	Other diseases	Total for disease
Employees from the U.S.	1907	2.56	1.16	6.05	7.21
	1908	2.20	1.10	4.38	5.48
	1909	2.33	.17	4.28	4.45
	1910	2.63	.00	3.13	3.13
	1911	2.16	.66	2.32	2.98
	1912	1.79	.32	3.73	4.05
Other white employees	1907	6.82	4.68	10.14	14.82
	1908	9.68	5.20	3.47	8.67
	1909	4.30	3.84	4.14	7.98
	1910	7.06	2.16	2.88	5.04
	1911	6.43	3.53	4.82	8.35
	1912	5.00	1.41	4.06	5.47
Colored employees	1906	–	7.80	–	49.01
	1907	3.60	4.15	25.53	29.68
	1908	3.52	.98	8.25	9.23
	1909	2.93	.73	7.18	7.91
	1910	3.23	.93	7.46	8.39
	1911	3.11	.57	7.67	8.24
	1912	2.61	.23	6.70	6.93

> natives. The European labourer, though he mingles with the natives, does not live with them; but the negro lives and sleeps in their houses, exposing himself constantly to the endemic malarial infection there prevalent. As long as he has a roof over his head and a yam or two to eat, he is content, and his ideal of personal hygiene is on a par with his conception of marital fidelity.

15.4 The racial death rates

It was impossible to obtain the full figures relating to each race for 1906, for in that year the statistics of the Europeans were not separated from those of the Americans; but Major Noble was good enough to give me an interesting table on the annual death rates among Canal Commission employees, broken down according to ethnic groups (see Table 15.4).

Table 15.5 Deaths of blackwater fever among black employees by country of origin, as diagnosed by autopsy.

Costa Rica	1	St Lucia	2
Monserrat	1	Mexico	1
Antigua	1	Grenada	1
Guadaloupe	1	Jamaica	2
Madeira	1	Barbados	83

A glance at these tables shows that the death rate of the American is lower than that of the other white races (Europeans, Spaniards, etc.), or of the coloured employees (black). Next to Americans come the Europeans.

When we look at the death rates from malaria, again the Americans come out lowest; but we now find that although the total death rate of the blacks is higher than that of the Europeans, their death rate from malaria is lower. This may seem strange when we remember that, although careless in their habits, most of the latter live in screened houses, while the negro is hardly at all protected; but the explanation is that a large proportion of the blacks come from malarious islands, and have acquired in infancy a certain amount of immunity to malaria. There are no statistics actually demonstrating the different incidence of malaria among the various black races, but Dr Darling gave me a striking piece of indirect evidence.

As is well known, all of the West Indian islands are malarious except Barbados, and were statistics available there can be no doubt it would be found the Barbadians were the chief sufferers from malaria. There are, however, statistics relating to blackwater fever, which is recognized to be in some way connected with malaria. Dr Darling gave me the following note on the cases which came to autopsy:

> Haemoglobinuric fever has occurred among the blacks as well as the whites, although to a less extent; there is a marked preponderance of cases among negroes from Barbados, and relatively few from the other islanders. It is well known that Barbados is the only one of the West Indies free from malaria. The following table [Table 15.5] shows the nativity incidence of haemoglobinuric fever.
>
> Very respectfully, S. T. Darling (Chief of Laboratory).

15.5 Pneumonia

On the other hand, the coloured races are very susceptible to pneumonia, and this disease carried off large numbers in 1906 and 1907. By 1908 it had become much less prevalent, and one of the most interesting questions is: *Did pneumonia disappear as the result of the negro's obedience to sanitary orders, or because he refused to be controlled?*

It is now recognized that malaria, by lowering the resistance of a population, raises the death rate from all causes, and the experience in India as well as elsewhere has been

that pneumonia and malaria are often connected. Drs Deeks and James have shown that the seasonal curve of the two diseases in 1906 and 1907 was not the same; and that after 1907, while malaria although diminished retained its seasonal increases, yet pneumonia, although diminished, was very irregular, and not seasonal in incidence.

It has been suggested by Colonel Gorgas, I think, that the pneumonia disappeared partly because the negroes left the Commission quarters and went to live in isolated "shacks." In other words, that being more scattered, the disease had less chance of spreading by contact. This is very probable; but it is no less probable that the general resistance of the negro having been raised by the diminution of malaria, pneumonia has no longer been able to attack him unless he were peculiarly susceptible. When less than 100 cases occur per annum in a labour force of over 40,000 people, it is not to be expected that any seasonal curve of value can be worked out, or that any great connection between it and malaria can now exist.

The connection between malaria and pneumonia is one of practical interest, and at the time pneumonia was so prevalent, an investigation was carried out on the zone by a board, of which Dr H. R. Carter was chairman. Among their conclusions, they "found from the histories that malaria may prove a predisposing factor, as histories of continued fever for several days preceding the onset of the pneumonia were common."[1]

Dr Deeks states further on, in an analysis of 574 cases which were under his care:[2]

> The most striking factor in the above analysis, however, is the small number of cases complicated by malaria, only sixteen cases being recorded in which the organism was present. This observation has been repeatedly verified since, and it may be said in general terms that malaria organisms and leukocytosis are incompatible conditions in the human organism. Leukocytosis takes care of malaria, and in the treatment of pneumonia even the presence of organisms need not be considered in the general management of the case.
>
> On the other hand, it may be noted here that leukopenia, which is present in typhoid fever, is not incompatible with malaria, and here these two affections are found almost constantly to exist, and necessitate the administration of quinine through the whole or a great part of the course of the former.

These observations are of great interest from many points of view. We know that, although blackwater fever is due to malaria parasites, these disappear very rapidly from the blood when the actual attack of blackwater comes on. It would almost appear as if something similar occurred when pneumonia sets in, and that the increased number of leukocyte called out to deal with the pneumonia germs incidentally destroy the malaria parasites. In this way evidence would be lost of the part which malaria played in predisposing the patient to pneumonia. In the Federated Malay States I have seen only two outbreaks of pneumonia on estates; and both estates were malarious. Of course, isolated cases of pneumonia are frequent; the outbreaks I refer to were epidemic in character.

On the Rand, in South Africa, which is a non-malarious elevated region, the negro races show a similar liability to pneumonia. It has been shown that a high percentage

[1] "Pneumonia on the Isthmus of Panama," by W. E. Deeks, *Medical Record*, New York, October 1908. [2] *Ibid.*

of the labourers harbour malaria parasites; that the disease occurs chiefly among the new arrivals; and that there is, if not overcrowding in the labourers' quarters, certainly no special allowance of floor and air space. Under these circumstances, where malaria can only be the result of an infection before arrival, it is not impossible that the change to the cold climate lowers the resistance of the labourer to his malaria parasites, and also to the pneumonia germs. It would be interesting to learn what percentage of the pneumonia patients on the Rand show evidence of malaria infection at the time of the pneumonia attack, or immediately before it. As the high mortality in the mines has received and is receiving the most careful consideration, it is to be hoped this point will be investigated, if already it has not received attention.

15.6 Yellow fever extinguished

It is now so long since yellow fever was stamped out on the zone, that people have almost forgotten this brilliant achievement. When he went to the zone, Colonel Gorgas was confident he could eliminate it[1] "by the same methods that were so successfully adopted in Havana;" and he has justified that confidence, for the zone has been free from the disease since 1906. The public water supplies were opened on the 4th July 1905, and from Table 15.6, which is taken from Mr Bishop's book,[2] it will be seen how quickly after that yellow fever disappeared, to which happy event the strenuous exertions of the Sanitary Department in abolishing rainwater barrels and other breeding places of the *Stegomyia* as rapidly as possible materially contributed.

15.7 Malaria

It was about malaria that Colonel Gorgas had most anxiety. In Havana he had organized a scheme of mosquito destruction which, "though entirely directed against yellow fever, was almost equally successful against malaria." He felt confident that he could eliminate yellow fever from Panama; "but malaria, in my opinion, is the disease on which the success of our sanitary measures at Panama will depend. If we can control malaria, I feel very little anxiety about other diseases. If we do not control malaria our mortality is going to be very heavy."[3]

How wonderfully he has controlled malaria will be seen from the chart in Figure 15.1. Year by year the amount of malaria has diminished, until in 1913 no trace of the seasonal rise during wet weather can be seen.

Table 15.7 shows the actual number of cases of malaria admitted to hospital, the labour force, and the admission rate per 1000 of labour force. If malaria has not been completely stamped out, it has been reduced to less than a tenth of what it was. In 1913, among the white employees from the United States, there was only one death from malaria and one from blackwater fever. I have not got the figures for 1913 relating to deportations from the zone for illness, but no white employee from the United States was invalided from the zone on account of malaria during the years 1910, 1911, or 1912.

[1] *Report on the Isthmian Canal*, W. C. Gorgas, 24th May 1904. [2] *The Panama Gateway*, Bishop, p. 243.
[3] *Report on the Isthmian Canal*, W. C. Gorgas, 25th May 1904.

Table 15.6 Statistics of the last yellow fever epidemic on the Isthmus, 1904–5

		Total		Employees		Place of origin			
Year	Month	Cases	Deaths	Cases	Deaths	Panama	Colon	Canal zone	Foreign ports
1904	July	2	2	2	2	2	–	–	–
	Aug.	–	–	–	–	–	–	–	–
	Sept.	1	–	–	–	1	–	–	–
	Oct.	2	–	–	–	–	–	–	–
	Nov.	2	–	–	–	–	–	–	–
	Dec.	6	1	2	–	5	1	–	–
1905	Jan.	19	8	7	1	8	1	1	9
	Feb.	14	9	5	3	10	–	2	2
	March	11	3	6	–	7	4	–	–
	April	9	3	7	3	8	1	–	–
	May	33	7	22	3	16	14	3	1
	June	62	19	34	6	29	17	13	3
	July	42	13	27	10	15	9	8	10
	Aug.	27	9	12	1	11	10	5	1
	Sept.	7	4	3	3	5	–	1	1
	Oct.	5	3	3	2	4	1	–	–
	Nov.	3	3	1	1	1	2	–	–
	Dec.	1	–	1	–	–	1	–	–

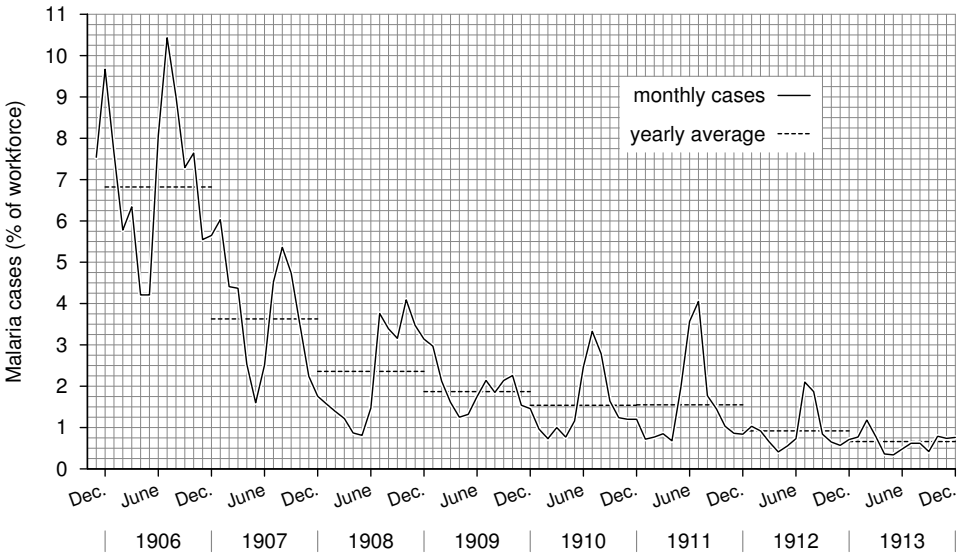


Figure 15.1 Malaria incidence in the Canal Zone from 1906–1913

Table 15.7 Malaria cases and hospital admission in the Canal Zone, 1906–1913

Year	No. of cases	Labour force	Admission rate per 1000
1906	21,739	26,705	821
1907	16,753	39,343	424
1908	12,372	43,890	282
1909	10,169	47,167	215
1910	9,487	50,802	187
1911	8,987	48,876	184
1912	5,623	50,893	110
1913	4,284	56,654	76

Indeed, for the year 1912, only fifteen United States employees were invalided from all causes, including injuries.

I have already emphasised the fact that most of the negroes do not live in screened houses, and that many live in "shacks" on the edge of or in the jungle. A few, only those who live in houses with a water supply and water closet, comply with any sanitary regulations, but none conform to any regulation for the control of malaria. None are under any restriction as to where they go or when. The same freedom of movement applies to both Americans and Europeans; and the greater incidence of malaria among the Europeans can be attributed to their carelessness in frequenting negro quarters at night, and their general disregard of all sanitary precautions against malaria. It is perfectly true that malaria has not been completely abolished; but it must not be forgotten first, that many negroes live in huts close to and in the jungle (in 1913 they were being rapidly removed for military reasons); and secondly, that many thousands of blacks already infected with malaria arrive from the islands. These people suffer from relapses after their arrival, which swell the hospital returns; and the absence in 1913 of the seasonal rise in the malaria curve shows conclusively that most of the existing malaria is now the result of relapses.

Nor should it be forgotten that the Sanitary Department has had to work under many disadvantages. The chief difficulty has been that the sanitarian could not adopt the best method of eliminating the disease, namely, drainage. Drainage systems have had to be destroyed by the engineers time after time, so that they might dispose of the spoil from the Cut. This constant interference with drainage led to the continual creation of new swamps, which had to be controlled by oiling. Indeed, engineering work of all kinds has so frequently changed the minor as well as the major features of the topography of the zone, that the sanitary and divisional inspectors have had to be forever on the watch for new breeding places. In an ordinary town or village, one who is in the habit of searching for mosquito larvae knows exactly where all the breeding places are; nor does he find them to vary even over a period of many years. This reduces the amount of supervision very greatly, but in Panama it is not so.

Again, in Panama many places were occupied only for a short time, and it was not advisable to carry out any permanent drainage. Places like Juan Grande, Mamei, and Old Frijoles were under the lake in 1913; and several other places have since disappeared under its waters. Where only temporary occupation was contemplated, only temporary measures of control were adopted; and such measures are less certain than drainage. Perhaps one of the greatest disadvantages under which the Government has worked has been the artificial condition of the whole zone. The Americans are building a great highway for commerce and war, and for the latter object defence from the attack of any enemy is imperative. It was to give security from bombardment by a hostile fleet that the locks were built about seven miles in from the ocean. As a safeguard against the land operations of an enemy the whole zone, except at a few stations, is being allowed to revert to jungle; indeed it has been depopulated, so that it must revert to jungle. Now we have seen that in the Federated Malay States, and as we shall see later in British Guiana also, the development of agriculture is the most effectual way of eliminating malaria under certain conditions. In Panama they have not had any assistance whatever from agriculture.

Before concluding I would make two more observations. The first is that although malaria had been controlled in places like Ismailia and Klang before the Americans went to Panama, the reports from these places would have been of comparatively little value to a sanitarian working under the peculiar conditions that exist in the Isthmus, if, indeed, they would not have been actually misleading. It may be said, therefore, that practically the whole of the anti-malaria work in Panama is original; as such it was at first largely experimental, and we can trace, I think, certain modifications in the original plan in later years.

Need I emphasise how difficult his task is when the sanitarian has not only to carry out a scheme of sanitation, but has also to invent it?

Secondly, I would point out that during the whole period under review, thousands of people, many of whom were highly susceptible to malaria, have poured into the zone each year; and this is, almost more than anything else, the circumstance which produces the severest outbursts of malaria. In conclusion, we can say that with almost everything against it, and tested by this the severest test, the Department of Sanitation comes out triumphant.

15.8 Malaria in small stations and camps

I have already said that many stations were small or were only occupied temporarily, and it is among these that we see how quickly the Department brought malaria under control. For Toro Point I have already given figures which illustrate this (see Table 10.2). Major Noble has kindly supplied me with the figures relating to several other places.[1]

15.8.1 Juan Grande Camp. This was in Gorgona district, and was occupied temporarily by Spaniards. It is now under the lake. The anti-malarial measures consisted of a

[1] These figures were tabulated in the running text of the original edition but have here been moved to the Appendix.

little draining, but mainly screening, oiling, and bush clearing close to the camp. Table A.1 shows the percentage of the labour force sent to hospital for malaria each week.

15.8.2 Mamei Camp. This also was in the Gorgona district, and is also now under the lake. No less striking have the results been here (see Table A.2).

15.8.3 Empire. Here there is now a permanent drainage system and comparatively little oiling is required. But in 1907 drainage was less advanced and there was a good deal of malaria. The contrast between 1907 and 1912 is indeed wonderful (see Table A.4).

15.9 Mosquito catching and screening

The protection obtained from screening ordinary railway trucks and catching each morning all mosquitoes that have gained an entrance, is undoubtedly most valuable, and the highest credit must be given to the Sanitary Department for evolving a method which could be put into practice in many places where nothing else could possibly have saved a construction force from practical annihilation. In a conversation Colonel Goethals told me that some of the worst cases of malaria on the Isthmus had occurred among the members of the party who were out in the jungle camps surveying the watershed of the Chagres River and what were to be the limits of the future Gatun Lake. "Chagres fever" or "jungle fever" was always specially dreaded for its severity, the reason for this being of course that in such jungle very large numbers of *Anopheles* occur, and the inhabitants of small camps, some of whom are sure to bring malaria with them, are constantly being reinfected, so that no sooner have they overcome one set of malarial invaders than they have to meet another.

Mr Le Prince gives an illustration of the value of these methods of protection in Ross' *Prevention of Malaria*, and Dr Orenstein gives other illustrations;[1] but I need not reproduce these here, after having given such striking examples as Juan Grande and Mamei.

Mosquito catching without screening, is, I believe, also of great value; but I have no figures in support of this. An opportunity of seeing the value of mosquito catching alone on a large scale was to occur at the end of 1913, when some of the troops were to go into camp; but so far I have not seen the actual figures.

15.10 Other Diseases

Dysentery, typhoid, and all other diseases have been reduced in a way just less striking than yellow fever. To illustrate the saving of life from all diseases the Sanitary Department prepared in 1910 an interesting table called "The Isthmian Canal Commission, in account with the preventable diseases." It shows the changes in death rate due to infectious diseases that are amenable to sanitary prevention, between 1884, the year in which the French workforce was at maximum strength, and 1909, the peak year of the American workforce (see Figure 15.2).

[1] "Mosquito Catching in Dwellings in the Prophylaxis of Malaria," *American Journal of Public Health*, vol. iii, No. 2.

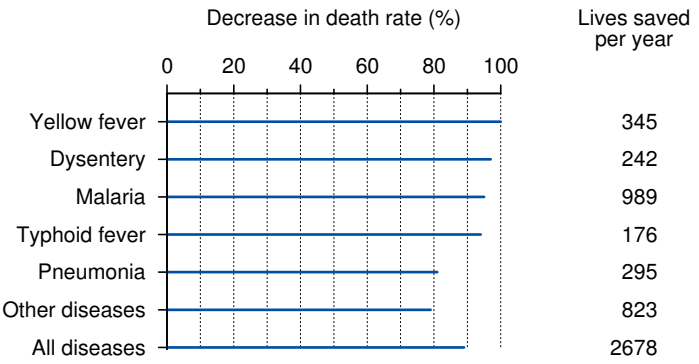


Figure 15.2 Changes in death rates for diseases amenable to sanitary administration, between 1884 and 1909

Since then the *amount to the credit*[1] of the Department has steadily increased, and the total of lives saved to the end of 1913 amounts to practically 30,000.

15.11 Deportations

It has been said that the low death rates are the result of the Department shipping to the United States or to their homes all those who are likely to die. Of all tropical countries, it is probably true that immigrants do seek to return to their original homes when ill (it is one of our original animal instincts); but in the case of Panama it will be seen from the following tables that deportation plays practically no part in lowering the death rate of the very large population from whom the deportees are drawn. Even if every person deported had died on the zone, it would have had very little effect on the statistics; while, as a matter of fact, many, such as the insane, would probably recover, whether sent home or allowed to remain on the zone; and although some of the injured might not be able to earn a living, few would probably die since they had recovered sufficiently to be moved. Major Noble was good enough to furnish me with full details of the deportations from the year 1906 to 1912. It does not seem necessary to give them in full, so I will condense them all except that for the year 1912.

It seems to me that these tables dispose of the statement that the low death rate is artificial. I have reproduced them, however, because there is no doubt of the *bona fides* of those who made the statement; I have heard it in the United States, in Europe, and in Asia.

15.12 Immigrants Rejected

Each year the number refused landing is published. In 1913 the total number refused admission at Colon-Cristobal and Panama-Ancon—that is, at the two ends of the Canal — was only 59 out of a total of 87,961 passengers inspected. Disease of the eyes, tra-

[1] This phrase references the design of the original graphic, which is styled loosely resembling a balance sheet (see Section A.2). This design has not been replicated in the redrawn figure. (M. P.)

Table 15.8 Deportations by category, 1906–1911

Category	Year					
	1906	1907	1908	1909	1910	1911
Black	110	66	97	81	87	107
White	175	80	117	86	67	79
Male	175	143	212	157	146	171
Female	0	3	2	10	8	6
Employees	152	133	197	143	137	161
Non-employees	23	13	17	24	17	16
Malaria	55	14	3	5	2	4
Tubercle	15	56	95	63	60	40
Insane	14	15	8	28	33	19
Dysentery	8	8	–	–	–	–
Alcohol	5	–	–	–	–	–
Injury	13	9	20	12	26	60
Beri-Beri	9	–	–	–	–	–
Nephritis	4	11	33	12	4	11
Rheumatism	6	–	–	–	–	–
Heart etc.	6	14	12	5	3	10
Nervous system	5	–	–	–	–	–
Miscellaneous	35	27	42	42	36	33

Table 15.9 Deportations by nationality, 1912

Nationality	Black	White	Male	Female	Employees	Non-employees	Malaria	Tubercle	Insane	Injury	Nephritis	Heart etc.	Miscellaneous
U.S.A	–	19	19	–	15	4	–	5	1	3	1	–	9
Canada	–	1	1	–	1	–	–	–	1	–	–	–	–
Spain	–	48	48	–	39	9	4	4	13	12	3	1	11
Other Europeans	–	12	12	–	11	1	1	5	–	3	1	–	2
Jamaica	46	–	39	7	31	15	1	5	12	12	5	3	8
Barbados	36	–	35	1	30	6	1	9	12	10	–	2	2
Martinique and Guadeloupe	10	–	9	1	8	2	–	2	–	2	1	–	5
Other W.I. Islands	27	–	27	–	24	3	–	9	2	6	2	3	5
Latin America	3	1	4	–	4	–	–	2	–	2	–	–	–
Total	122	81	194	9	163	40	7	41	41	50	13	9	42

choma, is the chief cause of rejection, so it is obvious that rejection of immigrants does not play any real part in lowering the death rate, as has also been suggested.

15.13 The Number of Employees

It has been suggested that the number of employees upon which the statistics are based, is incorrect; that the population is not so great as the figures; and that consequently the death rate is higher than is given. At the bottom of this suggestion there is the microscopic particle of truth upon which most false statements are founded. On the zone it is, of course, impossible to take a monthly census of the people; and for statistical purposes the number on the payrolls is taken as the monthly population. That a certain number of the men stop work, go to another part of the Canal, represent themselves as new arrivals, and re-enrol, is of course possible; but there is not the slightest reason to suppose that the number who do this can possibly invalidate the statistics.

The fact seems to be that the success of the sanitary work on the Canal has been so far beyond men's dreams of what could be done, that they deliberately refuse to believe it, and raise the most absurd arguments in support of their disbelief. The modern man is distinctly sceptical of fairy tales and miracles, whether ancient or modern; and he places the mosquito theory among the fairy tales. So when the modern knight dons his wire-gauze armour, leaps jauntily over an open drain, couches his tile-pipe in its rest, tilts at and slays the mighty midge, to free, not one fair maiden, but a whole dusky race, the modern onlooker is provoked first to amusement and then to scepticism. Finally, he may learn the mosquito may be, after all, mightier than the dragon, and a vast deal more real; but many are still in the sceptical and puzzled stage, and the laugh really is on the side of the knight as he watches the modern man try to explain away the modern dragon and the modern miracle.

Yet my experience of the men of the Sanitary Department was that they recognized in the frankest way not only how far they had been successful, but also in what way they had fallen short of success. Not only was there no attempt to conceal anything, but my attention was drawn time and again to what could be improved, and where they had failed. Indeed the great charm about my visit to the zone, was the frankness of every member of the Sanitary Department whom I met.

16. Panama: the cost of sanitation

When completed in 1915 the Canal will have cost approximately 350 million dollars, of which 20 million will have been spent by the Sanitary Department; that is, about 5½ percent of the total will have been spent on sanitation. Ten percent of the total cost is allowed for contingencies in most engineering estimates, and the cost of sanitation at Panama has come well within that allowance. The expenditure on sanitation has led to saving in many directions; but the actual return may be stated briefly as follows:

The Canal has been constructed. Without the Sanitary Department the Canal could not have been made, for it would not have been possible to assemble the large labour force of both whites and blacks necessary for so great a work, had yellow fever and malaria existed in the terrible epidemic form in which these diseases are seen, when large numbers of susceptible people are continually being introduced to an endemic area. Even had it been possible to obtain the labour, the costs would have mounted up to far beyond 5 percent of the present total. It is well within the truth to say that, had there been no Department of Sanitation, and had neither money, men, nor time been of account, the Canal would have cost three times as much in money, ten times as much in lives, and would not have been completed in three times as many years. We will, however, miss the chief lesson the Sanitary Department of Panama teaches, if we content ourselves with these figures; for an analysis of the expenditure brings out in a remarkable way how much cheaper it is to prevent than to cure disease.

Before going into details it must be explained what the functions of the Sanitary Department are; and that, as Colonel Gorgas says:[1]

> Much the larger part of the expenses of the Department of Sanitation for the Isthmus has no relation to sanitation. This came about gradually. During the first two years of preparatory work on the Isthmus there were only three departments—Government, Engineering, and Sanitary. All functions that did not manifestly fall under the head of government or engineering were assigned to the Sanitary Department. If we compare the functions performed by the Sanitary Department of the Isthmus with those performed by a city government in the United States we will find that the Sanitary Department on the Isthmus performs the same functions as the city government of New York City, with the exception of the accounting system, the judiciary, and the police.
>
> The ordinary man, in speaking of the Sanitary Department, has in mind a department such as the Health Department of New York. Besides performing such functions as the Health Department of New York performs, the Sanitary Department on the Isthmus cares

[1] "The Expenses necessary for Sanitation in the Tropics," by W. C. Gorgas, *Pres. Address to Amer. Soc. Trop. Med.*, 1910.

> for all the sick, both in the hospitals and in the dispensaries, administers the national quarantine, does the street cleaning and garbage collecting, fills in and reclaims waste lands, pays the salaries of some fifteen ministers of the gospel, cares for all the cemeteries, does a general under- taking and embalming business for some 80,000 people, and besides all this, pays directly to the Engineering Department some $200,000 per year.

Colonel Gorgas then goes on to explain how the actual appropriations are expended, and shows that the appropriation for sanitation has been at the rate of $3.38 per capita per annum or 28 cents a month. Then he adds:[1]

> But these figures could be still further reduced if we were an independent Sanitary Department here on the Isthmus, with the object simply of doing the work we are at present doing. But sanitation is not our primary object. We are here as a part of a great organization for building a canal, and we have to fit into this organization, irrespective of whether it is advantageous for the Sanitary Department or not.
>
> For instance we find a piece of swamp land belonging to the Panama railroad. As the Panama railroad is owned by the Government we cannot make them abate this nuisance. So in order to preserve health conditions we have to ask Congress for $100,000 with which to fill it in. We do this, and the day after the work is finished the Panama railroad rents the land on a rental basis of $200,000. Of course this is an excellent business for the United States. It spends $100,000 and immediately clears 100 percent. But it calls the work 'sanitation,' makes the Sanitary Department pay for it, but pockets all the profits that arise therefrom. If the Sanitary Department on the Isthmus were the ordinary Health Department of one of our home cities there would be no expense involved in abating the above nuisance. A transaction in just about the circumstances and figures as described above has occurred to the Sanitary Department on the Isthmus.

I was much interested to find that in Panama enterprising officers contrived to make profits for their own departments at the expense of the Sanitary Department. Exactly the same thing has occurred in the Federated Malay States time and again, and soon after the Malaria Advisory Board came into existence, I drew attention to the heavy expenditure for "filling" in order to convert a swamp into a building site, when for a mere fraction of the money spent, the swamp could have been drained sufficiently well to prevent it being a public danger. A government can often afford a small sum for draining, when it cannot meet the heavy charge for filling; and it is essential that the sanitary officer should be on his guard to prevent his department from being so exploited that his proposals are rejected to the great loss of the community.

16.1 The Department of Municipal Engineering

When the Americans came to the Isthmus, they found that in neither the city of Panama nor Colon was there any sanitary organization whatever, and the first thing they did was to create a Department of Municipal Engineering. It existed until August 1908, when its work was taken over by various divisions of the Construction Department.

> During the four years of its activity it expended nearly $6,000,000, of which about $2,250,000 was for waterworks, sewers, and pavements in the city of Panama and Colon,

[1] Gorgas, *ibid.*

> and about $3,500,000 for work in the Canal zone. Subsequent expenditures in Colon and Panama brought the total cost of improvements made in them by the Commission up to nearly $3,500,000. All of this, in accordance with the treaty between the United States and Panama, will be paid back to the United States through water and sewerage rates, within a period of fifty years, at the expiration of which the system of waterworks and sewers within city limits will revert to the cities, and the use of water will be free to their inhabitants, with the exception of a sufficient water rate necessary for maintenance and operation.
>
> Through these expenditures pure water was supplied to the cities of Panama and Colon, and all settlements in the Canal zone, the cities were converted from hotbeds of disease—without water supplies or decent pavements or sewers—into the best-paved, best-watered, and best-sewered cities in Central or South America.[1]

From this it will be seen that almost one-third of the whole amount debited to the Sanitary Department was expended on permanent works, most of which will be a great asset to the Republic of Panama, long after the construction force on the Canal has disappeared; and it is absurd to debit the construction force with the whole of this expenditure; the most that ought to be charged is such a sum as will pay an ordinary rate of interest on a proportionate share of the capital and the sinking fund.

While, of course, the whole sum expended by the Municipal Engineering Department was necessary for the public health, in an ordinary community it would appear not in the accounts of the Sanitary Department but in those of the Municipal Engineer. Personally I think it perfectly legitimate to charge it to the Sanitary Department, as has been done in Panama; nor need the Department shrink from the responsibility for the expenditure, for no money spent on the Isthmus has given a better return; but when comparisons with the costs of other sanitary departments are being made, it is important to keep this point in view.

16.2 Scavengings

To the Sanitary Department is also charged the cost of the collection and disposal of garbage, and this alone up to 1912 amounted to more than half a million of dollars.

16.3 Buildings and Quarantine

The cost of the buildings used by all engaged in the work of the Sanitary Department is also debited to the Department: so, too, is the money spent on repairs. These items amount to over a million dollars, while quarantine amounts to over $300,000.

16.4 Administration

Under this heading there is a sum close on $800,000, which certainly has no parallel in the accounts of any other Sanitary Department. Through this account sanitation is charged with such curious items as a share of the Isthmian Canal Commission Band, the Y.M.C.A. clubhouses, and the official newspaper called the Canal Record. Referring to this subject Colonel Gorgas says:[2]

[1] *Panama Gateway* p. 241. [2] Gorgas, *ibid.*

> The overhead charges consist of such items as expenses of accounting, division, expenses of Pay Department, expenses of quarters, salaries of higher officials not connected with the Sanitary Department. While these charges may be just, they are not customary. In discussing the expense of the Health Department of New York, no one would think of including in it a charge for the Auditing Department, a charge for the Pay Department, a charge for the Mayor's salary, a charge for the Governor's salary, etc.

16.5 Hospitals

The care of the sick is also paid for by the Sanitary Department. Up to 1912, over $7,000,000 had been spent on hospitals, and when the Canal is opened the total sum will be close on $9,000,000, or almost one-half of the grand total expenditure of the Department of Sanitation in the ten and a half years of its existence. However useful the hospitals may have been, they have very little claim to be considered essential expenditure in the prevention of disease, even in the case of diseases like yellow fever or malaria.

Of course public opinion in America demanded the sick should be looked after as well as if they had been in the United States, and the splendid hospitals on the zone are the result. Had they not existed the cost of the Department would have been almost halved, while the total death rate of the zone would have been comparatively little higher. Colonel Gorgas himself points out that while sanitation cost them only 28 cents a month, the medical and hospital care of the employees and their families cost 2.6 cents per day, that is, 78 cents a month. It is important that this should be made clear, for when a government has only a limited sum to spend on hospitals and sanitation, it will do more good to the community by spending on prevention than on cure. It may seem brutal to put it so bluntly, but as a matter of fact the choice is made every year by every government, and one of the great lessons of Panama has been the demonstration to the whole world that it is not only better but actually cheaper to prevent disease than to cure it.

16.6 Sanitation proper

To come to sanitation proper now, almost suggests it is the Cinderella of the family; and indeed we find that, including the water supplies, sewers, etc., the total cost of this will not exceed $5,000,000, or just over one-quarter of the total expenditure. Lest some should imagine I represent the cost of the prevention of disease as less than it really is, I reproduce, from the Annual Report for the Fiscal year ending 30th June 1912, Table 5, Appendix 1 (Department of Examination of Accounts), the total expenditure to that date (see Table 16.1).

From the table we see that, while hospitals cost $7,077,577.74, sanitation proper in Colon, Panama, and the Canal zone up to the 30th June 1912 cost only the sum of $4,966,368.62; or at the rate of $624,548.07 per annum. The population during that period has averaged approximately 115,000, so that the cost per head for sanitation proper works out at $5.43 per annum, 45.2 cents a month, or 1$^1/_2$ cents a day. To many it may appear that the cost of sanitation is very high, and that a rate of over £1 sterling

Table 16.1 Detailed statement of the classified expenditures of the Department of Sanitation, from the beginning of the work until June 30th 1912. All amounts are in $U.S.

	Total fiscal year 1912	Total to June 30th 1912
Administration	86,378.11	776,451.27
Hospitals and asylums		
Medical storehouses, Colon	9,360.33	31,564,14
Ancon Hospital	426,383.65	3,291,621.41
Colon Hospital	195,558.90	1,718,234.40
Tobago Sanatorium	33,869.50	100,356.88
Santo Tomas Hospital	10,601.51	50,622.16
Other hospitals, dispensaries, and sick camps	194,093.01	1,885,178.75
Quarantine	35,861.36	324,966.27
Sanitation, Panama and Colon		
Sanitation proper, Panama	38,960.58	769,255.23
Disposal of garbage, street cleaning, etc., Panama	10,627.34	70,374.05
Sanitation proper, Colon	29,007.61	528,891.00
Disposal of garbage, street cleaning, Colon	8,045.16	36,619.93
Zone Sanitation		
Sanitation proper	409,205.84	3,644,222.39
Disposal of garbage, street cleaning, etc.	100,762.20	421,072.01
Construction of buildings	8,409.44	1,033,891.46
Repair of buildings	23,236.58	77,472.62
Total department of sanitation	620,391.12	14,814,793.97

per head per annum would be prohibitive for other lands; but the conversion of dollars into other currencies is entirely misleading in a matter like this. In the first place the lowest paid labourer gets 10 cents an hour and usually earns a dollar a day, so that to him the tax would probably amount to less than 2 percent of his annual salary. To put it another way, if he denies himself each month two bottles of Balboa beer—"The Best Beer Brewed"—he would save sufficient for his sanitation. I admit it would be a self-denying ordinance, for the beer was excellent; but perhaps this humble illustration will serve to show how necessary it is to consider a person's income when trying to estimate the weight of a tax.

There is another way of viewing this expenditure, and it would be one which might occur to the agriculturist: it is to regard it as so much per acre. This can be found very simply. In the ten years sanitation proper will have cost approximately $6,000,000 or $600,000 per annum. The area under control is 50 square miles or 32,000 acres, so

the cost per acre per annum is $18.75 or about £3,10s sterling. No tropical product, unless it contrived to produce an everlasting "boom," could afford to spend so much on sanitation. But to think of it in this way is to overlook the peculiar conditions which exist in the Isthmus as described in Chapter 11, and to which I shall in a moment again refer. These conditions are such that they could not possibly exist in an agricultural community, and to discuss this way of regarding the expenditure is therefore a waste of time.

In the second place a very large part—almost a half—of the expenditure on sanitation has gone in wages. Had wages been lower, the cost of sanitation would also have been lower; almost an instance of tempering the wind. Thirdly, I have explained already that the water supplies, sewers, etc., will remain as assets for many years, and that it is absurd to debit the rates with the whole capital cost in the space of eight or ten years.

In the foregoing I have tried to show how the expenditure has been incurred, and I have attempted to answer on their own lines the arguments which have been used by those who accuse the Department of Sanitation of extravagance. All such arguments miss the real point. Of a truth the critics have lost the saving sense of humour when they accuse Colonel Gorgas of extravagance. Have they entirely forgotten that he has done what in the history of the whole world has never been done before, and he has done what perhaps only half a dozen men in the world believe could possibly be done? When a man does what to the world is a miracle, it ill becomes the world to grumble at the cost; least of all have they an excuse when the money spent has enabled an undertaking of unparalleled magnitude to be carried out at a fraction of what otherwise it would have cost in both money and lives. If every cent spent by the Department of Sanitation had been expended on the prevention of disease, the Department could still claim its place as the most important cost-reducing factor on the zone; nor could any one dispute its right to the supreme position among labour-saving appliances even in this great engineering work, where the last invention of human ingenuity finds full employment.

It is only the simplest justice to Colonel Gorgas and his staff to remember that he did not go to the Isthmus to work out the most economical way of freeing the tropics in general from the pestilences which make them so fatal to the human race. He went to assist in the construction of the greatest engineering work hitherto attempted. His task was one in many ways absolutely unique. It is true he was not hampered by want of money; in every other respect the difficulties with which he had to contend have no parallel in the ordinary conditions met with either in towns or villages in the tropics. In places which were occupied only for a short time, and in others where the engineers were continually creating new mosquito breeding places, it was impossible for him to lay down permanent drainage systems which are, in the end, both the cheapest and most effectual. What he did was to surmount every obstacle in his path, by devising and developing other methods when prevented from employing the best he knew. In this way he did what those who sent him to the Isthmus asked him to try to do—namely, he made it possible to establish the large labour force without which the Canal could not be constructed. No impartial or reasonable person can for a moment object to costs which have reached only 5 percent of the total cost of the undertaking, and without

which the undertaking would surely have ended in the failure from which it so narrowly escaped in 1906, when for a time work had to be abandoned, and when, as Mr Bishop has so graphically described, “nothing except lack of sailing accommodation prevented the scattering" of the entire force.”

Colonel Gorgas has done something more than what he was sent to do, important though the great Canal is to the commerce of both the New and the Old Worlds. Although he went to construct a canal, he has also conducted a School of Applied Sanitation whose lesson will benefit the world—I say with confidence—for all time.

I believe, indeed, that because the conditions were unique, the lesson of Panama has its limitations; and that, because the value of agriculture in controlling malaria, under certain conditions, did not come within the experience of the sanitarian in Panama, he did not emphasise it. Of supreme and last importance is the great lesson of Panama that, when everything else fails, and when all the conditions are most adverse, the adoption of one of the subsidiary methods which they have evolved will enable people to live, if not completely free from disease, at least with far greater freedom than we ever imagined could ever be possible; and that where large masses of tropical labour are employed, the appalling mortality of the past need not recur in the future.

17. British Guiana

17.1 Introductory

Of British Guiana I had often heard from Dr Daniels, when he was Director of the Institute for Medical Research, Federated Malay States, and I was now looking forward with interest to my visit to it, even if it could be only a short one. In British Guiana Dr Daniels had demonstrated in 1895 that malaria affected young children, and that as they grew older they gradually became immune, an observation frequently, but wrongly, attributed to Koch. I was aware, therefore, that malaria existed in British Guiana. I had often heard, too, of how the Dutch had reclaimed so much of the land from the sea; of the sea defences, the great drainage canals, and the tide gates; of miles and miles of estates all below high tide level. It seemed an ideal country to test the theory that agriculture abolished malaria on flat land, and a special interest was given to the inquiry from the knowledge that the most important malaria-carrying mosquitoes of Panama were also to be found in British Guiana.

The sanitarian, pent up in the jungle at Panama, had seemed to be always on the defensive. True, it was a brilliant defence; but still the enemy had not been killed, and, if precautions were relaxed, would return in full force at once. What was the condition in British Guiana? Had agriculture attacked the enemy and driven it out, once and for all? This was the chief point I wished to determine; everything else was comparatively insignificant. If it was found that, where properly cultivated, British Guiana was free from malaria, then men might surely hope to control malaria in any land, in any part of the world. As my visit lasted only ten days, it will be best if I record what I saw from day to day, so that the reader may judge for himself the value of my views.

At daylight on the 13th June 1913, the S.S. *Crown of Grenada* was somewhere off the mouth of the Demerara River, rolling unpleasantly in an easterly swell. Nothing could be seen of the low-lying coastline; but at nine o'clock we sighted a lightship, picked up a pilot, and turned towards where the shore was supposed to be. That land could not be far off, we concluded from the muddy water through which we ploughed, and within half an hour we saw the tops of the trees and the higher buildings of Georgetown, which is situated at the mouth of the Demerara River.

British Guiana does not look much on a map of South America, but in reality it is a large country. It lies between the 1st and 6th degrees of north latitude, and longitude 59° west runs through it from end to end. Only the coastline, a low-lying belt 10 to 40 miles wide, has been opened up. Behind this comes "a broader and slightly more elevated

Table 17.1 Mortality of labourers and children on estates in British Guiana, 1911–12

Group	Mortality (%)
Indentured labourers	1.73
Unindentured labourers	2.53
Children	3.10

tract of land composed of sandy and clayey, practically sedimentary soils,"[1] in which sand dunes are to be found rising from 50 to 100 feet above the sea level. Behind those are three great ranges of mountains, and several smaller groups, the eastern portion of which is forest clad, while on the west there are extensive grass clad savannahs. Several large rivers traverse the land, but owing to numerous cataracts and waterfalls they are practically useless for navigation. For this reason railways are necessary if the country is to be opened up.

Having presented my letters of introduction, and said what I was specially interested in, the Hon. Acting Surgeon-General, Dr Rowland, kindly gave me all the reports available; and as great attention had been paid to the subject of malaria on the sugar estates for several years, I was at once put into possession of much valuable information. Of special value were the spleen rates of many estates taken in 1911, and charts and tables of the malaria admissions to estate hospitals, before and after systematic dosing with quinine had been begun. In the report on the spleen rates, I found that hardly an estate in the country had less than 50 percent of enlarged spleens, which indicated a high degree of malaria infection; but on the other hand the death rates were distinctly low. In the Report of the Immigration Agent-General for the year 1911–12, I found the percentages of mortality of the mean population during the year were as stated in Table 17.1.

Such low death rates, where malaria was so high as to be represented by spleen rates of 50, did not fit in with my experience, and I was unable to understand it. Although the Courantyne coast was said to be the healthiest of all and freest from malaria, even there the spleen rates were from 15 to 60. The agricultural theory seemed to have broken down completely as regards the flat coast land, so there remained only the question of what would be found in hill land. There were only two hill estates in the country, both on the Essequibo River, and it was arranged I should visit one of these. As the steamer for the Essequibo did not sail until Tuesday, and this was Saturday, I had an opportunity of seeing something of Georgetown, under the guidance of the Hon. Dr Rowland, Dr K. S. Wise, and Dr E. P. Minett.

Georgetown, the capital of the colony, is on the low alluvial coast land, and is protected from the sea by sea defences, like other parts of the coast. Being in low, flat land, roads could be made only by excavating the adjoining land, so the town has a large canal or drain almost wherever it has a street. The streets are laid out at right angles to each other and are well kept; the public buildings and many of the private houses are handsome, and the town has good reason to be proud of itself in these respects.

[1] *Handbook of British Guiana*, 1913.

On the 15th and 16th I examined various drains and trenches in the town. In the grass at the side of the trench in the centre of Carmichael Street I found many *Anopheles* larvae, some of which developed into *A. albimanus*. This trench was closed at each end by cross streets; in the next section it was being filled up. In a similar closed trench next the hospital no larvae were found, but this had the appearance of having just been filled by recent rains. Further along I came to a trench of another kind: it was deeper, and the level of the water was on a level with the road or nearly so; as I learned afterwards this was one of the canals which bring water into the town. Here a careful search among grass and debris failed to discover a single larva, nor was anything found in the large trenches on each side of the railway.

At Camp Street I turned towards the sea wall; many larvae were found among some dead leaves in an isolated stagnant pool by the side of the road; but in a large trench on the east side, where the vegetation was alive and the water cleaner, only a single small larva was found. I walked back by the sea wall, having confirmed what I had seen in Panama, that *A. albimanus* is very partial to the smaller collections of water and to debris. I had found larvae easily enough, and if they were always and everywhere as abundant, there was no difficulty in explaining the high spleen rates. It looked as if *A. albimanus* would always find a sufficient number of breeding places in any country in which it existed to ensure a safe passage for the malaria parasite from one man to another; in other words, that wherever *A. albimanus* existed at all, it would be so abundant that the place would be intensely malarious.

On the following day I resumed my search in the East Street trench, drawing a blank as before; nor was anything found in the canal, where a feathery weed was so abundant that battalions of larvae might have found shelter. The Lamaha Canal brings water into the town from the savannahs; it is raised above the level of the streets. On each side there is a small ditch; but in these no *Anopheles* larvae were found even in masses of fine algae, although *Culex* was common enough.

Wandering into the beautiful Botanical Gardens I was searching the lily ponds without capturing anything, when the superintendent captured me. I explained what I was looking for, and asked if in any of the other ponds there was more dead vegetation than in the one I was examining. I was then taken to a pond where sea cow (manatees) had eaten up all the vegetation; not a larva could be found. In the manatee, the sanitarian appeared to have found an ally, and he dilated on the idea of introducing it into all canals as an anti-mosquito measure. The botanist stood it for a time only, and then broke in, “But what about the aquatic vegetation?”

Calling upon Professor Harrison, Director of the Department of Science and Agriculture, whose house is in the Gardens, I met Mr Bancroft, late of the Federated Malay States Agricultural Department. He had only recently been transferred; indeed only six months before we had travelled together in the Federated Malay States, and now we had met on the opposite side of the globe, each having travelled in the opposite direction to the other. It was another instance of the friends a traveller meets in the most unexpected places.

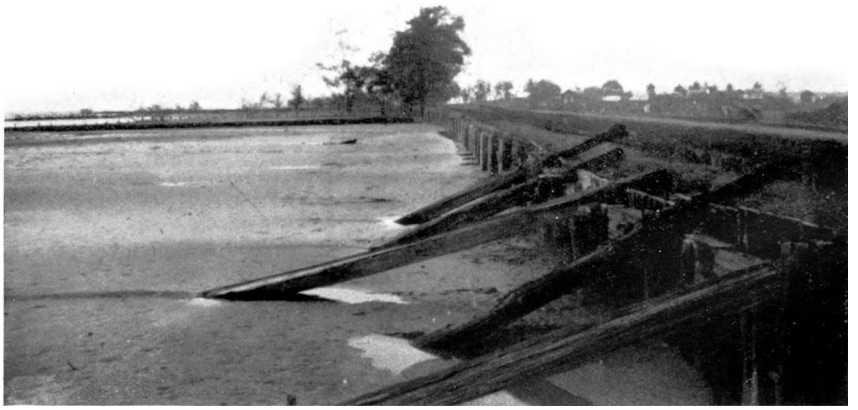


Figure 17.1 British Guiana: A portion of the sea defences where it had been repaired by greenheart timber

In the evening Dr Rowland drove me six miles out the East Coast Road, where I had an opportunity of seeing more of the sea defences. The Coast Road runs parallel to, and a short distance within the sea wall, which here consists of earth without any stone facing. On the sea side of the wall mangrove is encouraged to grow, for it is a great protection against wave action. At one point the sea had recently breached the wall, and it had been rebuilt with a facing of greenheart, a fine timber whose home is British Guiana. On the inland side of the road no jungle or forest was visible; for the first few miles, indeed, the land was like a grass park, quite uncultivated, with negro houses dotted here and there, round which there were occasionally a few bushes. Further out we came to places where scrub had grown to a height of 20 to 30 feet, and the land had reverted to genuine swamp. Dr Rowland told me that all the land along the sea front had been under sugar at one time, but becoming impoverished, had been abandoned by the estates which now cultivated the land further inland.

In a country like what we were now travelling in, one expects to see borrow-pits by the side of the road; but here the number of such pits was quite extraordinary, in fact, the land along the road was literally honeycombed by borrow-pits for many yards beyond the original roadside drain. The reason for these pits is the impossibility of getting stone to metal the roads, consequently the surface of the roads has to be covered by burnt clay which is taken from the pits. As roads with any considerable traffic have to be re-metalled each year, it is easy to understand why so large a number of borrow-pits already exist; and unless some substitute for burnt clay is found, it is equally clear thousands of other borrow-pits will have to be dug. As those isolated borrow-pits are suitable breeding places for *A. albimanus*, the upkeep of the roads which is necessary for the public convenience appears to be in direct conflict with the public health. Indeed, the Medical Department had already represented this to the Department of Public Works; but having discovered that it was only isolated borrow-pits that were dangerous, the

recommendation was that all borrow-pits should be connected up with the roadside drains. I have no doubt that as the advice of the Medical Department is sound, it will be followed in time; but as far as I could make out, no attention had been paid to the recommendation so far.

After visiting a negro village, the name of which I have forgotten, and seeing how the negro, like the Malay, allows his house to be smothered in fruit trees and weeds, we turned back to Georgetown. It was now getting dusk, and I then experienced the attacks of *Culex taeniorhynchus* for the first time. Although our horse was being driven at an ordinary running pace, the Victoria was full of the mosquitoes, and we were constantly being attacked. These mosquitoes were so abundant at times, so I was told, that if a donkey was left out in the fields all night it would be found dead in the morning. At the time I did not feel called upon to do more than listen to this tale; but before I left British Guiana, further acquaintance with this mosquito made me believe it capable of any crime.

17.2 Breeding places of mosquitoes in Georgetown

An examination of the mosquito breeding places had been carried out in 1910 and 1911 by Dr Wise, whose report was published,[1] and from that paper I extract some of his observations:

> The Anopheline mosquitoes (nearly always *Cellia albipes*,[2] occasionally *Cellia argyritarsis* were found breeding in nearly all trenches where overgrown with vegetation, both in the city and environs. Where no vegetation was permitted no Anopheline larvae were discovered. These mosquitoes were also found breeding in the hollowed-out stumps of trees which had been cut down in the lots and by the roadside. Numerous Anopheline larvae may be found during the rainy seasons, in the small grass-grown cross drains of the Queenstown district. They may occasionally be met with in cocoa nutshells, and in the grass-grown pools and trenches around the barracks.

This certainly was not very hopeful reading; it looked as if the whole colony would have to be "clean weeded," as we say in the Federated Malay States (i.e., to have all aquatic vegetation removed), if malaria were to be abolished. Since the operation would have to be repeated about every two or three weeks, it would not be possible to do it, and the prospects of eradication of the disease hardly seemed worth discussing.

Of the breeding places of other mosquitoes Dr Wise also gives a description. The great breeding place of *Aedes calopus* (i.e., *Stegomyia fasciata*, the yellow fever carrier) is the water vat which is attached to each house. The water supply for the town comes in an open trench, the Lamaha Canal, from an empoldered area ten miles from the town. It is a peaty brown water, and is not used for drinking or cooking. Drinking water is "collected from the roofs, and conserved in large wooden vats and iron cisterns. Of these vats, 63.9 percent were effectively screened. One thousand three hundred and ninety-six vats had more or less defective covers nullifying any beneficial effect of screening." In the examination 2560 premises were entered and examined, and of these 1490 were found breeding mosquitoes somewhere at the time of inspection. Dr Wise

[1] *Annals of Tropical Medicine and Parasitology*, Dec. 1911. [2] i.e., *A. albimanus*.—M. W.

makes special note of the amount of scrub in the city, and of how this conceals tins and other breeding places.

In another paper Drs Wise and Minett deal critically with "Rain as a Drinking Water Supply in British Guiana,"[1] and show that

1. before rain the water is good;
2. just after rain a great pollution occurs, and the water is totally unfit for consumption;
3. pollution slowly disappears, till from the fourteenth day onwards the water is again fit to drink.

There are two chief reasons for the pollution of the tanks in Georgetown; one is the carrion crow, which, picking up the "most indescribable filth and carrion," takes it to the roofs of the houses, and there eats it; the other is, that many of the water receptacles are simply leaky old iron tanks sunk in the ground, often close to cesspits.

As typhoid fever is far from uncommon at present, and yellow fever may at any time arrive to sweep through a population which has been free from it for almost a generation, Georgetown is certainly sitting on a volcano. The water problem is acute, but no less is it difficult. It may be possible to purify and decolorise the Lamaha supply so as to make it fit for drinking; the deep bore now being put down may find good water; or it may be necessary to go inland to the hills for a pure supply. The authorities are fully alive to the gravity of the situation. They are determined to solve the problem; but it is far from an easy one, either physically as regards the source of the water, or financially in regard to the money, for this is complicated by the Constitution of the colony.

When British Guiana came finally into the possession of the British in 1814–15, the land was cultivated by slaves, and this continued to be the labour until the Emancipation in 1834 brought the planters face to face with ruin:[2]

> Continuous and steady work was what the planter required, and this was just the thing the free negro was incapable of giving. The planters, faced with ruin, had recourse to immigration, and the history of the development of this system from its first crude efforts, through its many and sometimes almost fatal mistakes, to the present day, when it has been justly described as a model for all the world, makes an interesting study.

I do not propose to follow that at the moment, beyond remarking that the Emancipation upset the system of taxation which had been "a certain sum per head for each slave," and that for many years the Government had difficulties in getting their "supplies" voted; ultimately, in 1891, the Constitution was changed; votes were given to every male person who possessed certain and not very restrictive qualifications, and the financial power of the country passed from the hands of the Governor. How the experiment will work out in the end, I do not propose to speculate about, but the immediate result is that since the Governor cannot guarantee the security, the Colonial Office will not approve of loans, without which it is impossible to carry out great public works, like water supplies and railways. How strangely different this history is from that of the Federated Malay States.

[1] *Journal of London School of Tropical Medicine*, vol. ii., part 1. [2] *The British Guiana Handbook*, p. 71.

17.3 The Hills Estate

On Tuesday, 17th June, I started off in one of Sproston's steamers for the "Hills Estate" on the Masaruni River, one of the tributaries of the Essequibo. The sail was interesting, but I need not describe it. On arrival at the estate, I discovered that the manager, Mr Withers, had been in the Federated Malay States in the early days, so we had much to talk about. I made a careful examination of a number of drains on the estate, especially those at the foot of a hill near to some nurseries, but neither there nor in any other drain on the estate did I find a larva, even among the grass which grew in some of them. The land was undulating; in the Federated Malay States it would have been very unhealthy; but there was no history of fever on the estate, and Mr and Mrs Withers and their little girl certainly did not look the victims of the disease. As the labour force consisted largely of adults, I made no spleen examination.

On my return journey, I left the steamer at Tuschen, and trained to Georgetown, or at least to the opposite side of the Demerara, so as to get a view of the country.

17.4 Flat Coast Land Estates

On the 19th Dr Wise took me to Plantation Uitvlugt by motor car, on the way to which we passed Gladstone's Estate "Vreed-on-Hoop," about which controversy raged so fiercely at the Emancipation time. The road to the estate had a good surface, was dead level, and so should have been good driving; but unfortunately the devils of China seem to have come to British Guiana and made the roads with a maximum number of turns, so that they could practice turning, which is said to be to them an almost impossible operation. Anyhow, whether the Chinese devils inspired it or not, the road took a right angle turn every few hundred yards, and we progressed by taking three sides of every block we came to. Visitors are told the reason for these turns is that the road follows old estate roads which were always either at right angles or parallel to the sea. That may be so; I prefer the Chinese devil theory, it is more in keeping with one's mood after a motor run on such a road.

All the estates on the coast are of the same shape, and their irrigation and drainage systems are easily understood. When the Dutch began sugar cultivation and wanted to make estates, they threw up a polder or dyke close to the sea, below high-water mark, to keep the sea out. About four miles behind this they built another dyke to keep the estate from being flooded from behind, and also to dam up water for their irrigation channels. They threw up banks about every half mile at right angles to the sea, which cut up the land into estates about four miles deep and half a mile wide. To drain the estates large drains were dug down each side boundary; a number of subsidiary drains at right angles to these were also cut, but the latter did not run from side to side of the estate for a reason which will be apparent in a moment. As the outlet of drains was below high-tide level, large tide gates called "kokers" were built; these were opened during ebb tide, and closed as soon as the seawater attempted to flow into the estate. They were worked by hand.

In addition to the drainage system, which takes water off the estate, another system of channels brings water in from the empoldered area or swamp behind. The quantity

Figure 17.2 British Guiana: A "koker," or hand-worked tide gate

of water admitted is regulated by a gate, similar to the "koker" on the outlet. It flows in a main channel down the centre of the estate, and the subsidiary irrigation channels gridiron with, but do not connect with, the subsidiary drains. In this way the water level of the estate is under complete control, which is essential in a crop like sugar. The irrigation channel is also used as a navigation channel for the barges which bring the sugar canes from the field ("cane piece" is the curious local name) to the factory; water transport is a valuable means of reducing the cost of handling so heavy a product as canes.

As I have said, all the estates are the same, but many have abandoned the fields nearest to the sea, and many of them are now growing rice under the care of the East Indian population who have settled permanently in the Colony.

17.5 Uitvlugt Estate

I had chosen to visit this estate because in the Surgeon-General's report the statistics showed its spleen rate to be very high (see Table 17.2).

In January, no less than 285 children out of 352 or 85 percent had enlarged spleen. At the later examination in July, a much larger number of the children had been seen; few could have escaped, and the result was to show that out of 632 no less than 420 or 66 percent suffered from enlarged spleen, or in other words from malaria.

The figures given in the special malaria report showed that malaria had diminished very remarkably in the past few years, subsequent to the distribution of quinine; and Dr Wise furnished me with the figures given in Table 17.3, which are more complete

Table 17.2 Spleen rates among children on Uitvlugt Plantation, British Guiana. Rates are given for both January and July 1911.

Month	Spleen size	Ages			
		1–3	4–8	9–12	Total
January	Normal	29	14	4	47
	Enlarged to edge of ribs	34	66	31	131
	Enlarged from edge of ribs to umbilicus	17	67	30	114
	Enlarged beyond umbilicus	6	21	13	40
July	Normal	60	102	50	212
	Enlarged to edge of ribs	46	150	57	253
	Enlarged from edge of ribs to umbilicus	18	83	45	146
	Enlarged beyond umbilicus	2	15	4	21

Table 17.3 Malaria prevalence on Uitvlugt estate, British Guiana, from 1906 to 1913.

Year	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13
Average population	3444	3794	4101	4501	4593	4659	4678
Fever cases	2371	1522	1104	1054	797	553	142
Oz. quinine distributed[1]	–	–	–	–	747	1965	1285

[1] Quinine distribution not recorded before 1910.

than those given in the special report, inasmuch as they give the population each year instead of an average.

The diminution of the fever rate was most satisfactory; that it had been the result of quinine in doses which averaged only ten grains a month to each of the whole population appeared to me very remarkable when the high spleen rate is taken into account. In the Report of the Immigration Agent-General for 1911–12 the number of deaths for Uitvlugt is given as 60, which on a population of 4659 gives a death rate of 12.8 per 1000. The total cases admitted to hospital for the year was 2090, and 18 were treated as outpatients.

I was completely at a loss to understand these figures. With a spleen rate of 60 the death rate in the Federated Malay States would have been over 100 per 1000, and I had poured 20 grains of quinine a day into coolies for months without getting results that even distantly approached the Uitvlugt figures. Nor did the explanation of the mystery appear any nearer when, out of about forty or fifty children Dr Wise and I examined, only four had enlarged spleen. I then asked the native medical officer how spleens were examined on the estate. He said the child was laid flat on the table, and the spleen was then percussed. It was recorded as enlarged if the area of dulness was over the normal, even if the spleen could not be felt.

Figure 17.3 British Guiana: a hospital used by a group of estates

Here then was the explanation. In order to overlook no enlarged spleen, the greatest care had been taken in the examination; but unfortunately as this is not the method of examining and recording enlarged spleens in other countries, it gives a wrong impression to those who record as enlarged only what can be felt by the hand. To adjust the difference it would be necessary to exclude probably all those recorded as "enlarged to edge of ribs," and perhaps some of the next group "enlarged from edge of ribs to umbilicus," for foods in various parts of the intestinal tract would give a dull note to percussion which might have been interpreted as enlarged spleen. If we include in normal the group recorded as "enlarged to edge of ribs," the spleen rates drop at once from 85 and 66 to 46 and 26; while if part of the next group is included they come to nearly what Dr Wise and I found, about 10 percent. If this was the correct interpretation of the figures recorded, then the whole mystery was solved. Malaria did exist, but to only a small fraction of what the recorded spleen rate would indicate; and of course where malaria is not intense, quinine gives the excellent results which had in fact been obtained.

In a moment the whole aspect of the malaria problem had altered. The spleen rates of the whole country had probably been obtained in this way; they had in fact been recorded as much higher than they really were, and when they were properly discounted, the low death rates would be explained. With the high spleen rates went the fear that malaria would never be overcome; that *A. albimanus* would never be driven out by agriculture; that it would never be possible to free the people of British Guiana from this pestilence.

The hospital is built on pillars 10 feet high. The floor is of wood. Beds with mattress and blankets are arranged in four rows up the ward. Male and female patients are separated by a partition. Separate wards are not provided for patients of different na-

Figure 17.4 New Amsterdam, British Guiana. The photograph shows a trench full of vegetation in which *Anopheles* have never been found. The Rev. Mr Aitken has had it under observation for many years.

tionality or dysentery cases. The staff consists of a sick nurse and the usual complement of attendants.

17.6 Plantations: Diamond, Providence and Farm

In the evening I visited this group of estates which are situated along the east bank of the Demerara River. They are under Mr Fleming, as attorney and general manager. Dr Fergusson, the medical officer of Peter's Hall district has paid special attention to the coolies, dosing them systematically with both thymol and quinine, and their health is good. Mr Fleming has also given the medical officers strong support in their efforts to lower the death rates of his plantations. On Plantation Providence a most efficient latrine was devised; it is a corrugated iron shed placed over one of the small lateral drains of the estate. Unlike the others this drain is connected with the irrigation trench by means of a 6-inch pipe, consequently it is constantly flushed and never becomes objectionable. This form of latrine has been adopted by a number of other estates. Next to a proper sewer system, this is the most satisfactory way of dealing with the night soil of a native labour force.

On one of this group of estates I saw a large tank or well, surrounded by wire netting; the coolies draw water from it by means of a small semi-rotatory hand pump.

17.7 The Courantyne

In a much more hopeful spirit, I sailed the same night for New Amsterdam to visit the Courantyne coast, which was reported as being the healthiest part of British Guiana. I was also anxious to meet the Rev. James Aitken, who with Dr Rowland had made such

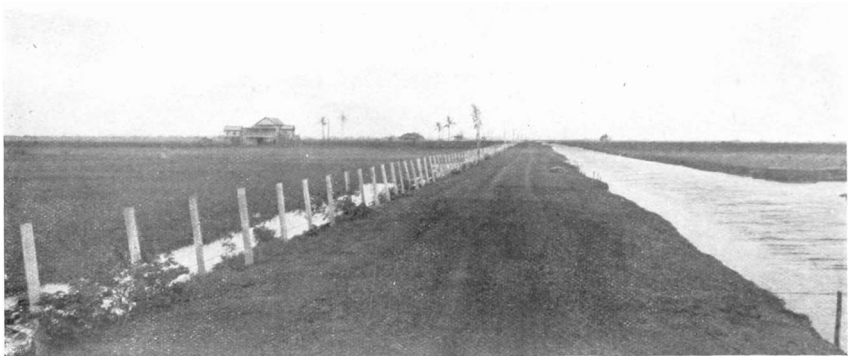


Figure 17.5 British Guiana: a portion of the road from New Amsterdam to Port Mourant, showing how flat the country is, and how much practically stagnant water exists.

valuable and extensive investigations into the mosquitoes of British Guiana, that the insects of that region are better known than in nine out of ten places in the tropics. Arriving at daylight I was met by Mr Aitken, and discovered in a short time that we had been fellow students at Glasgow University more than twenty years before.

Mr Aitken told me that he had been in British Guiana for nine years, during which period he had had only two attacks of fever; the first was six years after his arrival. His wife had been seven years in the country and had never been attacked. He told me that after a drought in the previous year which had killed out the fish in a pond in his garden, *A. albimanus* had appeared in it in large numbers. It was quite exceptional to find larvae where there were fish. There were certain places containing water where he had never got larvae, such as the large trench behind the town; for over a year he had made constant observations of it without ever getting larvae. I saw this trench later in the day; it was full of vegetation, and at first sight appeared to be an ideal place for larvae, but I found none.

After seeing Mr Aitken's collection of insects, and satisfying myself that his *C. albipes* was identical with *A. albimanus* of Panama, we started in a motor car for Port Mourant. The country was absolutely flat, and in places was beautiful open grazing land for miles at a stretch. During the American Givil War it had been under cotton, but when the war stopped, so did the cotton growing, and now it is just possible to trace the lines of the old drains. In wet weather it becomes a lake, but it dries evenly, and does not breed Anophelines, so I was told. The existence of bush giving shade to a pool favours larvae. At several places we searched the roadside drains for larvae but found none; there were, however, numerous small fishes. The roadside drains were full of grass, as they are in other flat countries with heavy rainfall.

At Port Mourant, we breakfasted with Dr Kennard. His house is on the side of some rice fields, and in his compound there is a drain which he says does not breed *Anopheles* if cleaned out about twice a year. After breakfast we walked through the rice fields, which had just been planted, to the "nigger yard" of Plantation Port Mourant. This is divided up into the "indentured yard" and the "free yard." The former conforms to the

Figure 17.6 British Guiana: The Port Mourant Estate. On the right are the houses of the indentured coolies. On the left, many hundreds of acres of rice swamps.

Table 17.4 Malaria prevalence on Port Mourant estate, British Guiana, from 1906 to 1913.

Year	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13
Average population	5060	5228	5275	4328	4462	4612	4727
Fever cases	461	618	243	383	193	57	65
Oz. quinine distributed[1]	–	–	–	–	100¼	388	463

[1] Quinine distribution not recorded before 1910.

Government regulations; the buildings are all of the approved type plan, and the yard is under a short grass. The free yard shows the labourers' capacity for architectural variety and town planning: huts and shacks built anyhow and anywhere would be another way of putting it. In the free yard, rice swamps and houses are more or less mixed up; the indentured yard had no swamps actually in it, but immediately over the fence and within 100 feet of the nearest buildings there was a stretch of 3000 acres of rice swamp.

With such conditions present, one would have expected to find malaria severe, but the actual figures were as listed in Table 17.4. It would be difficult to find a place in the tropics much freer from malaria than this, for it must not be forgotten that immigrants may bring fever with them. It is much better than Panama at the best.

The spleen rates, however, were not so satisfactory as officially reported, and were as listed in Table 17.5. These figures give rates of 8 and 20 percent; but if we apply the correction which I suggested as regards Uitvlugt then the rates drop to under 2 both in January and July, and I suggest that this is the correct spleen rate.

Leaving the estate, we visited Rosehall school, where among 56 children not an enlarged spleen could be found.

Table 17.5 Spleen rates in Port Mourant in 1911

Spleen size	January	July
Normal	137	133
Enlarged to edge of ribs	10	34
Enlarged from edge of ribs to umbilicus	2	3
Enlarged beyond umbilicus	–	–

Plantation Albion was a mile farther on. The coolie yard was a short distance in from the road: it was like all the others. The coolie lines or ranges are buildings partitioned into five or six rooms; each room is 10 feet by 20; this includes the 6-foot verandah. The floor is a mixture of cow dung and whiting, and the coolies are compelled by law to keep it in good order. In the middle of the coolie yard is the "sweet water" trench or pond. It is filled from time to time from the navigation trench. The sides are grassy; it is not enclosed in any way, and when a coolie wants water he takes his own dish and dips into the trench.

Although the trench is open to dangerous pollution, the statistics of the country show that these open water supplies are much less dangerous than many would have us believe, and the experience of this estate has been the same as mine in the Federated Malay States: that where malaria is absent high death rates are quite exceptional. Of course were cholera to appear in the country, these drinking trenches might easily become polluted and cause devastation of the labour force; but that disease has fortunately been rarely imported to British Guiana in the past. It is not endemic, and since the time when coolies first came by steamer from India it has not appeared, nor is it likely to appear in the future.

The photograph in Figure 17.7B show the drinking-water tank as well as other collections of water which might be expected to breed *Anopheles*, but, as a matter of fact, we found none; nor in such places are they to be found. The trench in the foreground was full of a floating weed which had been blown by the wind to the end of the trench (the left of the photograph). It looked as if it might have harboured *Anopheles*; we found only *Culex* larvae, but these were in abundance. In all pools I was on the lookout for algae such as were specially associated with *A. albimanus* in Panama, but I saw none. Is the water of British Guiana not suitable for the growth of this particular kind of larvae food? Yet that can hardly be the sole cause of the absence of Anopheline larvae from the trenches; and if fish destroy *Anopheles* larvae, why do *Culex* escape?

Whatever is the explanation, there can be no doubt that malaria is by no means common on this estate. The figures for Albion are given in Table 17.6.

In 1911–12 the total admissions to hospital from all causes was 2368; the outpatients numbered 532. At the hospital I saw about a dozen coolies whom Dr Kennard called "loafers." There was nothing really the matter with them; they had learned that the hospital is a comfortable place and preferred staying in it to working. Being indentured coolies, they are sent to hospital if they do not work, and it is not always easy to prove

A

B

Figure 17.7 British Guiana: Albion plantation. A: The coolie yard. B: The coolie yard taken from the hospital. In the foreground is the navigation trench, with floating vegetation blown to the left. In the centre is the drinking water trench.

to a magistrate such people are really shamming. The "loafer" is a difficult problem in all countries; but the fact that the percentage of convictions to the total indentured population amounted to 14.7, 35 percent of which were cases of habitual idleness, shows the employers of British Guiana are imposed upon by a considerable number of coolies; and such a gang as I saw swell the admission rate to hospital without representing any

Table 17.6 Malaria prevalence on Albion estate, British Guiana, from 1906 to 1913.

Year	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12	1912–13
Average population	3750	3613	3325	3569	3511	3411	3532
Fever cases	900	935	803	1755	846	338	364
Oz. quinine distributed[1]	–	–	100	162	481	649	1266

[1] Quinine distribution not recorded before 1908.

Table 17.7 Spleen rates on Albion Estate in 1911

Spleen size	January	July
Normal	325	281
Enlarged to edge of ribs	51	40
Enlarged from edge of ribs to umbilicus	2	–
Enlarged beyond umbilicus	1	–

real ill-health. If any further proof of the excellent health of this estate were necessary, it is in the fact that the death rate for 1911–12 was 11.1 per 1000.

In the Surgeon-General's Report I find the spleen census given in Table 17.7. These figures give spleen rates percent of 14.2 and 12.4. If we make the correction I suggest, they become less than 1 percent in January and zero in July.

Visiting the plantation school, I examined 113 children. One only had enlarged spleen, and the enlargement was very slight. On the way back we stopped at a school about a mile out of New Amsterdam. The pupils had left, but 19 were called back and examined; not one had enlarged spleen. In all I examined 188 children on the Courantyne coast, finding only one with enlarged spleen.

In the face of all the foregoing figures, it is clear that in this part of British Guiana agriculture has, in some way, for all practical purposes extinguished malaria. One thing is certain. Malaria has disappeared not because the pools, drains, trenches and rice fields have been oiled or weeded; not because the inhabitants have lived in screened houses; not because any of the subsidiary Panama methods have been employed to kill *Anopheles* adults or larvae. The country is non-malarious because the malaria-carrying *Anopheles* do not breed in the water in land which is cultivated in British Guiana.

Need I emphasise the importance of realising this? Confirming as it does similar experiences in the fiat land of the Federated Malay States, it means that in most tropical lands malaria will disappear as they become developed, without the special measures or organization found necessary in Panama where no cultivation has been allowed.

17.8 Rice fields in British Guiana

Of late years the Indian population has cultivated rice, and in 1911–12 the total area in the colony under this crop was 36,000 acres. To the colony it is a great asset, and

Table 17.8 Hospital admissions on an estate in British Guiana, 1908–10

Month	1908	1909	1910
July	71	153	46
August	72	198	73
September	132	260	77
October	111	311	118
November	95	336	159
December	58	133	107
January	46	66	66

it is looked upon with favour by the Government and the plantations in view of the uncertain future of the sugar industry. On the other hand, the medical men, bearing in mind the serious consequences which have followed the cultivation of rice in other countries, have looked upon the extension of rice cultivation with great anxiety. In a valuable paper entitled "Rice Fields and Malaria," Dr C. P. Kennard gives his views and experiences.[1] After referring to the views of Celli and Koch, who hold that rice fields produce or aggravate malaria, he says: "Of late years there has been a marked increase of malaria fever on this coast, coincident with the great extension of the rice industry there; beyond this increased rice cultivation there has been little change, drainage, other agricultural pursuits, and methods of living remain much the same." He then describes the process of rice cultivation and how *Anopheles* may live in the rice swamps. Then he goes on: "The question now arises, do the people living among the rice fields suffer more from malaria than elsewhere?" and the emphatic answer is given: "This is undoubtedly so." He then goes into the question of the time of year when malaria is at its worst; it would appear to be in September and October, when rice is being reaped. He also observed that when new fields are being brought under cultivation, malaria is more severe. He gives some figures relating to hospital admissions (see Table 17.8)[2] and comments:

> The marked rise in 1909 is attributed chiefly to a new settlement among some new rice fields, and the rise commencing early was probably due to some plots of land not being taken in, so that when irrigation occurred over the rest of the fields, with the rain, suitable pools were kept up in these plots among the bush, and in the immediate neighbourhood of the houses.

Dr Kennard finds "some consolation in the fact that the people who have lived for some years in the rice fields settlements become more or less immune from malaria," although he would have us remember that "not only are these settlements a danger to themselves but to the general community." Knowing that 66,000 acres of rice swamps in the Krian District of the Federated Malay States are practically free from malaria, and

[1] Timehri, *The Journal of the Royal Agricultural and Commercial Society of British Guiana*, December 1911.
[2] The reference (see preceding footnote; full text available from `archive.org`) does not name the particular estate or hospital in question. (M. P.)

that the labour force at Port Mourant in British Guiana is practically free from malaria, although it lives on the edge of an extensive rice field, I have much less fear of rice cultivation than Dr Kennard, and find in his own most valuable observations, which I am now about to print in extenso, the true way to prevent them ever becoming harmful.

> The *Anopheles* require shade to breed in. I have seen pools teeming with mosquito larvae in the open, but no *Anopheles* larvae there, although *Anopheles* were in the neighbourhood. They also require more or less clean water and absence of fish; fish will soon eat up any mosquito larvae they come across. When the rice is growing and the land is submerged, fish are all about, and I have never been able to find larvae among the growing rice in this condition.
>
> Some time back I was in a field which was covered with water and the rice nearly ready to cut. In this part of the field I could find no larvae, but many small fish. I also came across no *Anopheles*. In a part of the field where the water was drying up preparatory to the rice-cutting, small pools had been left in the depressions, and from two or three of these pools among the growing rice I was able to collect *Anopheles* larvae (from which I developed later on an *Anopheles* of the usual variety seen here, *A. argyritarsis* or *A. albitarsis*); at this spot I also came across two or three adult *Anopheles*. In a couple of days these pools were dry, so most of the larvae did not develop; but a little rain falling would have kept up the pools so that the larvae would have reached maturity.
>
> We have in that field a natural exhibition of what occurs in the rice fields generally—land submerged, fish present, no *Anopheles*—land drying up, clear pools with shade, no fish, *Anopheles*. We have therefore about the rice-reaping time a great increase of *Anopheles* bred under the favourable conditions above mentioned, and I need not point out that the absence of rains—heavy rains—irregular irrigation or drainage, or irregular level of land, will all make a difference in the formation of pools suitable for or against *Anopheles* breeding, and so varying local circumstances and effects; as for instance, land drying up with enough rain falling to keep up the pools, but not to flood the land, would be the most suitable for *Anopheles* breeding.
>
> *Anopheles* can also breed in the trenches connected with the rice fields if these have much weeds and growth; the fish prevent their multiplying much, but a few of the larvae may escape to develop to maturity. I have found a stray *Anopheles* larva with other mosquito larvae in such trenches. The trench on one side of my field is connected with the rice fields which surround it on two sides. At the early part of the year I had the trench weeded and all rushes cut down, and whereas previously I could nearly always find *Anopheles* in the house, since then they have been distinctly rare. It may be thought that, as the water drains off, enough fish would be left in the pools to destroy the larvae, but this is not so. When the water is going off the fish go with it mostly; they leave these small holes, but may remain in the larger ponds and depressions.

On these observations he frames the following rules:

> Firstly, no settlement shall be allowed in the rice fields.
>
> Secondly, no rice fields should be within 200 yards of the houses to the leeward, or within a quarter of a mile to the windward. The *Anopheles* is not a strong flyer, but is said to be able to travel at least over 100 yards. In Italy I believe there is a law preventing rice fields near the houses.

> Thirdly, the trenches connected with the rice fields should be kept clean and free from weeds, and the excess of water be properly conducted away from the fields and not swamping the surroundings, as is frequently seen and is one of the worst features in the rice fields near the villages; some of the villages are kept in a bad state of drainage or irrigation owing to this, and thus local foci for *Anopheles* breeding may be developed and kept up.
>
> Fourthly, the rice should be planted in each field or fields under the same common drainage or irrigation at the same time, so that it would be reaped at the same time, and the water could be regulated accordingly; thus there would be fewer pools about, and these would exist during shorter periods.
>
> Fifthly, at the time of reaping everybody working in the rice fields should take a daily dose of quinine; and in the rice settlements, if not abolished, they should commence this earlier and continue for a little time after the rice reaping.
>
> These methods I am sure would do away with a good deal of malaria in connection with the rice fields; they would not do away with it altogether, as there would still be the other influences unconnected with the rice fields in operation. I think, however, they would have the effect of restoring the Courantyne coast to its previous reputation of having little malaria, and with an increased population, better drainage, and other general anti-malarial precautions, this should be one of the first parts of the colony to get rid of the disease. As I have already said, I have dealt with the Courantyne coast as it is particularly known to me; the other parts of the colony must be affected by their rice fields in the same way and require the same precautions.

I am not prepared to endorse the statement about the flight of the *Anopheles*, and the restriction of dwelling houses to certain distances from swamps; but otherwise the regulations suggested appear to me to be exactly what is required; and if they are followed, British Guiana need have no fear of the extension of so valuable an industry as rice cultivation.

17.9 The Future

When the estates had just been opened up they had been unhealthy, and when the Indian coolies arrived to reopen the partially abandoned estates, their health had been most unsatisfactory. But as the years passed and good hospitals were established, the health became good, and the improvement was put down to the improved hospital system. I take leave to doubt this. I believe these estates were very malarious when first opened, and became so again when partially abandoned; but the improved health was in my opinion due to the land being put under cultivation; it was cultivation that drove out malaria.

It is true that on some of the estates malaria exists. It is shown by the lowered admission rates after quinine came to be administered more systematically; but I believe that the real way to eradicate the malaria is to eradicate the mosquito. Much is already known about the malaria-carrying mosquito in British Guiana, which should tell the medical officer where to look for it when he proposes to carry out an anti-mosquito campaign on an estate. The danger is in the smaller pools rather than the large trenches;

and if Port Mourant with its 3000 acres of rice fields is so free from malaria, it should not be impossible to bring other places up to the same standard, or even improve on it.

On the medical officers of British Guiana there is a great responsibility, as for them there is the great opportunity of conferring lasting benefit on the colony. The work must be done in the field and the village, not in the hospital, and the knowledge of the scientist must be yoked to the wisdom of the man of the world. Only in this way can be supplied that urgent need of British Guiana—a great industrial population. Although the estate coolies are healthy, the negro in his hut—built on a half-drained compound and smothered in bush—is far from being free from disease; and the infantile mortality is so high that the negro population is actually decreasing. The high infantile death rate is indeed the negro's chief asset; it keeps wages so high that if he works for a day he can retire to his hut for a week.

Before the days of beet, a sugar estate in British Guiana was a valuable property, both to the proprietor and to the colony. But the days of prosperity are gone. Now with the most rigid economy, the estates can just make ends meet; in a bad year there may be serious loss. Without the Indian coolie the estates could no longer be carried on. Provided with a comfortable home, cared for in a hospital when sick, and given what to him is a princely wage, the coolie has made a good bargain when he comes to British Guiana, and a population of over 120,000 East Indians shows he knows it. No less is it a good bargain for the estates. If there were no Indian coolies, no work could be done, and the estates would have to be closed. To the proprietors it would mean ruin; to the colony, the loss of most of its white population. If that occurred, it is difficult to see what is to prevent the negro, if not extinguished by disease, from relapsing almost into his original savage state, for the power of the Government would diminish as the country became more and more swallowed up in jungle.

I paint no fanciful fear. Ever before the planter is the fear that the Indian Government may prohibit immigration; it has been done before. But if from the existing material—the Negro and the East Indian—the medical officers build up a strong, healthy population, so abundant that it must work to live, and the healthier because it must work, then truly they will have saved British Guiana from barbarism and given it a place in the sun.

18. Barbados

Barbados stands apart from the other large West Indian Islands in several respects: geographically, in being some 200 miles to the east of the string of islands known as the Lesser Antilles; geologically, in being a coral upheaval while the others are, at least so I am informed, volcanic peaks; entomologically, in being the only island free from *Anopheles*; and medically, in being the only island free from endemic malaria. The connection between the absence of *Anopheles* and the absence of malaria is easily understood, but why *Anopheles* should be absent is not quite clear. It has been suggested that the island's geographical isolation has prevented the insect spreading to it from the other islands, but the generally accepted view is that it is due to the presence of a small minnow called the "millions." I am not able to accept this view, and am inclined to think there is some connection between the absence of *Anopheles* and the geological structure of the island.

Although the inhabitant of Barbados is not pestered by *Anopheles*, he is the victim of several other mosquitoes which breed in tins, cisterns, barrels, and water containers of that sort, and the name "Barbados leg" (elephantiasis) shows these other mosquitoes to be present in sufficient numbers to give the island a distinction of an unenviable character.

In 1905, Mr C. Kenrick Gibbons in a letter to the West Indian Committee Circular suggested that the absence of malaria was due to the presence in the streams and ponds of the "millions." These small fish are voracious feeders on the eggs, larvae, and pupae of mosquitoes, and it was thought that they destroyed all *Anopheles* in the ponds and streams; but that, since they could not reach *Culex* and *Stegomyia* larvae in artificial collections of water, these lived and flourished. Following on this suggestion, "millions" were sent to other islands; but, so far, I have not heard of any definite experiment showing a reduced spleen rate consequent on the introduction of the minnow.

Whatever the truth about the fish be, it is of importance that some definite experiment be undertaken. One of the smaller malarious islands should be stocked with "millions." It is not enough that "millions" be placed in a few streams, every stream and pool in either a half or the whole of an island should be well stocked with the fish. Malaria statistics should be carefully collected, and the other half of the island, or another island as the case may be, should be chosen as a control. This is an experiment which would cost almost nothing, while its importance is great.

Although I urge that a definite experiment be undertaken—for in a problem so great as that of malaria prevention we should try all things and assume nothing—my

impression is that the absence of malaria from Barbados is not so much connected with the presence of "millions," as with the geological structure of the island. Having heard that the island was composed mainly of a porous coral rock, I spent the short time at my disposal in seeing to what extent breeding places for *Anopheles* existed.

One of the first things that strikes a visitor to this tropical island is the absence of jungle. There is a large population on the island, and it is cultivated from end to end. Taking a motor car I ran some miles up the west coast in order to cross the streams which figure so freely on the map. Except at one spot where there was a foul puddle under a bridge, all the stream beds were dry; while all around were wide stretches of gently sloping fields, obviously dry. At one point turning down to the sea, I came to what appeared to be a small piece of level ground, seemingly a raised coral reef or beach, and here there was a ditch containing water and crowded with "millions." Returning towards the town, and crossing what on the map appears to be a considerable river, I found it to be dry also; and it is evidently dry at all times except during an actual rainstorm, for there was no sign of aquatic vegetation in its bed.

I then ran along the south coast, going out on a road well above the sea level, and returning by the shore road. Everywhere on the upper road the land was dry. The road surface, indeed, consisted simply of the soft coral rock. The rock had never been under pressure, and the branching of the coral was plainly visible in the roadside "cuttings." This portion of the island, therefore, consisted of a porous coraline rock, rather than a limestone such as we see in the English Downs, or Malay limestone formation. The shore road was on a ledge which appeared to be a coral reef or raised beach some 10 to 15 feet above sea level. Near to Worthing, about three miles from Bridgetown, a low-lying portion of the ledge formed a swamp of roughly 10 acres in area, divided up into canals and paths like much of the land seen in British Guiana.

I understand that in a small portion of the east coast, St Andrew's Parish, clay and sandstone appear, and that there the streams exist through the year; but I had no opportunity of visiting that portion of the island. I admit frankly that my visit was so brief that my views have not the weight which a longer stay might have given them; but being accustomed to visit places with the express object of detecting *Anopheles* breeding places, and having acquired a sufficient knowledge of country to know where to find water when it appears on the surface of the land, I am not disposed to think I can have overlooked many breeding places; indeed, in country so open as the portion of Barbados that I visited, the task of finding breeding places was peculiarly easy. One looks for water at the foot of a slope, where it forms a spring, or in river courses which convey the accumulated water of many springs. On stretches of gently sloping hill land such as forms the south and west of Barbados, water will not be found, unless some impervious stratum forces it to the surface. Now in Barbados, the only surface water I could find was a small puddle in a river bed and two water collections on level portions of the island. As these level portions are probably raised coral reefs, it is possible water will be found on other portions of old beaches; but when I consider the acres of dry land, and the scattered and limited nature of the surface water, I cannot believe that

malaria is absent from the portion of Barbados that I saw, for any reason other than the almost complete absence of breeding places.

In the brief allusion to Barbados, which I made in 1913,[1] time did not permit me to explain in full my reasons for doubting if the "millions" were entitled to all the credit they got. I do not deny that "millions" and many other fish and insects eat mosquito larvae, and had it been suggested that some of the trenches in British Guiana were free from *Anopheles* because of the "millions" and their allies, I should have hesitated to dissent; but to bring Barbados in support of the "millions" claim seems to me peculiarly unfortunate, since the possible *Anopheles* breeding places are so few and widely scattered. Barbados seems to me free from malaria because of the relative absence of breeding places, and to my mind that is because Barbados has natural subsoil drainage. Some such idea, too, may have been in the mind of the late Sir Rubert Boyce when he wrote:[2]

> We now know that the malaria-carrying mosquitoes, the Anophelines, appear to be absent from Barbados; most probably this is due to the fact that suitable conditions for their development do not exist. Owing to the nature of the soil, the storm water is rapidly carried off through the innumerable "sucks" which are everywhere to be found in the porous coral rock, and what permanent pools do exist seem to be perpetually stocked with minute fish—the millions which effectively get rid of any mosquito larvae.

If we assume that the actual area of water is sufficient to allow of malaria becoming established in the island, even then it does not follow that the "millions" are the cause, or even an important factor in the causation of the absence of *Anopheles*. Dr G. C. Low is inclined to regard the isolation of the island as important. It is 200 miles to the east of the other islands, and that means 200 miles against the prevailing north-easterly trade wind. The chance of mosquitoes arriving by sailing vessels is therefore remote; and if they arrived by steamers, which lie out in the open roadstead, they are still half a mile from the shore. Human carriage, therefore, does not favour the spread of the insect.

Even if a boatload of sturdy *Anopheles* were landed at Bridgetown and hastened to quarter themselves on the inhabitants, it is difficult to see how they are to propagate their species. The chances of any pregnant insect finding a breeding place a few miles out of the town, as for example the swamp at Worthing, and there can be few nearer, are as remote as those of their landing at all.

Finally, supposing *Anopheles* did land and did find a breeding place, is it certain that the fish is the cause of the mosquitoes' failure to thrive? Dr Low mentioned in the discussion which followed my paper, that he had found *Culex* and other larvae in the swamp at Worthing, just as he had noticed *Anopheles* larvae in Italy in waterways teeming with fish. I have seen many instances of the same in many lands, and have referred to the subject specially in this book in connection with a ravine in Sumatra, a swamp at Gatun in Panama, and a trench at Plantation Port Albion, in British Guiana. Dr Low's observation of the existence of the mosquito larvae and "millions" in the swamp at Worthing in Barbados, which appears to have been entirely overlooked by

[1] *Trans. Soc. of Tropical Medicine and Hygiene*, vol. vii., No. 2. [2] *Health Progress and Administration in the West Indies*, p. 145.

those who advocate the "millions" theory, is the last and final blow to the theory; for if "millions" are so voracious and so deadly to mosquito larvae in a pond, why do *Culex* larvae escape while *Anopheles* are utterly destroyed?

In searching for a reason for the absence of *Anopheles* from the Worthing swamp, Dr Low suspected that the chemical constitution of the water was unsuitable for the larvae, but on taking some of the water to another island he found *Anopheles* larvae bred freely in it. This test is, however, of little value, for the larvae of *A. albimanus*, with which Dr Low experimented, will breed out even when put into pure sea water.[1]

To sum up, it seems to me that (*a*) the general freedom of Barbados from malaria is due to the practical absence of surface water owing to the geological structure of the island; (*b*) that such ponds as exist are free from *Anopheles*, yet contain *Culex* larvae, for the same reason as certain trenches in British Guiana; and (*c*) that this is connected with the high state of cultivation in the island, the absence of jungle, and other, at present unknown, conditions governing mosquito life.

Again arises the question of why some mosquitoes breed in one class of breeding place and others in another; why some rice fields are free from *Anopheles* and malaria, and others full of both; and why it is possible to alter the species of *Anopheles* found in some places by altering the conditions of the breeding place, e.g., by drainage and clearing jungle. And again I would insist on the urgent need for a detailed study of the whole biology of the mosquito, for by this means I am convinced we will attain such knowledge as will give us power to say to some species "Come" and to others "Go," and will extend our control over malaria in a way that at the present time is almost beyond our dreams. But since in our present state of darkness we should neglect nothing, I strongly urge a definite scientific experiment with "millions" in one of the malarious West Indian Islands.

18.1 Conclusion

Before concluding I would like to speak of one thing more. For fourteen years the best way of giving effect to one of the greatest, and, for the tropics, certainly the greatest, discovery of medicine has been a matter of anxious consideration and thought to all responsible for the health and welfare of the tropical world. When the first transport of delight at Ross' great discovery had passed, a chill fell on men. They looked round on thousands of square miles of land and myriads of battalions of mosquitoes. Destroy these? Easier to count the hairs of the head or number the sands of the sea. Year by year, however, the way became clearer, and my task has been to trace something of what has been done in different parts of the world towards that end. To all it must be a joy and relief to find that opinion is now unanimous, and there are none, I think, who will not subscribe to the propositions in the following resolution on malaria passed by the Government of India at Simla on 23rd May 1914.

> The most important tropical disease is malaria. After allowance has been made for the tendency to attribute to fever deaths from other causes, malaria stands out as universally prevalent in India, and in many tracts is a scourge far greater than either plague or

[1] See Dr Darling's *Studies in Relation to Malaria*, chap. xiv.

cholera. It maims as well as kills, and causes more sickness, misery, and death than any other single disease. Measures for the prevention of malaria aim at breaking the cycle of infection in two ways: (*a*) by attacks on the parasites in man, and (*b*) by the destruction of mosquitoes. To the former class belong the different systems of quinine prophylaxis and treatment, and to the latter, all those measures which aim at abolishing mosquito breeding places. Both methods have been successful in other countries, and both have been tried extensively in India. The following propositions represent the experience gained up to date:

1. The conditions and causes underlying the prevalence of malaria vary greatly in different places, and no one anti-malarial measure is suitable for all.
2. Quinine both as a prophylactic and curative agent is of great value to the individual. Its powers of saving life, alleviating sickness, and destroying sources of infection cannot be overestimated. There should be no relaxation in the efforts to educate the people in the use of the drug; and its sale by shopkeepers in rural areas might well be encouraged.
3. The regular administration of quinine to children in schools during the malarial season is a practical measure of easy application and of proved utility; it is valuable alike for its immediate good effects on the health of the scholars and as a means of spreading knowledge of the use of quinine.
4. In any community under control quinine prophylaxis properly carried out is a valuable weapon in the fight against malaria: in India, with its free population, the ignorance and apathy of the masses, their prejudice against the drug, their objection to medicine when not actually suffering from illness, and the fact that it must be continued over an indefinite number of years, greatly limit the value of quinine prophylaxis.
5. In anti-larval operations it is not necessary to abolish all breeding grounds of mosquitoes, even of known carriers of malarial infection: a marked amelioration in health conditions will ensue if the chief breeding grounds of the malaria-carrying mosquitoes are cleared.
6. Malaria surveys have brought to light important and unexpected facts regarding the causation of malaria in particular localities. For instance, the enquiries of Major Listen and Dr Bentley in Bombay disclosed the fact that malaria did not arise from the swampy surroundings of the city, and that the malaria-carrying mosquito was *N. stephensi* which bred in the numerous wells attached to private houses. Again Major Christophers has demonstrated that malaria in the Andamans is due to a species of mosquito, *M. ludlowi*, which breeds in the brackish water of the creeks, and that the mosquitoes infesting the rice fields in the neighbourhood are innocuous.
7. Notwithstanding the initial expense, those anti-malarial measures should be chosen which will act automatically, be independent of outside help, and permanent in their effects; those which require regular repetition, constant attention or active cooperation on the part of the people, are, under present conditions, seldom durably effective.
8. The treatment of permanent collections of water is important whether it be effected by (*a*) watertidiness, through sloping of banks and clearing of weeds, or (*b*) stocking with fish of proved utility as mosquito destroyers or by both methods.

Here is a clear line of advance; but I am not without hope that the future will open up others, and extend more widely still the benefits of Ross' discovery.

19. Epilogue: the place of sanitation in tropical colonization

The problem of sanitation in the tropics, like most problems in the tropics and elsewhere, is primarily one of ways and means. That the sanitarian is trained primarily as a medical man is, in one respect, a handicap which he rarely overcomes; indeed, of its very existence he is seldom conscious. Yet this seems to me to be the source of many of his difficulties and failures, and lest this book should prove more a cause of stumbling than a help, in this closing chapter I invite the sanitarian to take a broad view of Life—Life as it really is to those whom he would serve; because I am confident that if he does so, he will avoid the chief dangers that beset his path.

The medical man is trained to look on the preservation of the life of his patient as an end to which everything is subordinate, and to attain which the cost need not be counted. His patient tells him that to gain the whole world is nothing, if he loses his life. It is true, too, that while there is life there is hope. Every medical man can recall how the spark of life has blazed up afresh in those on whose faces had already fallen that dread grey—the shadow of the valley of death.

Such things as these, striking a full measure of sympathy from the richest chords of the human heart, graven so deeply at a time when life is most impressionable, must influence the attitude of a medical man to human suffering and pain, surely as long as his life lasts. Indeed, were it not so, it seems to me he would be less than human. So it comes about that the sanitarian does not usually count the cost of his recommendation. One, indeed, bluntly said, "When I give an order, I don't bother about the cost." And when you ask him why the cost may be disregarded, he tells you it is because his order will lead to the saving of life, and nothing could be more important or beneficial. It has never occurred to him that sanitation has no monopoly of life-saving; yet it is so. And if the sanitarian wishes to do the maximum good and to avoid unnecessary friction, he must know something of the true proportions of life, and the real place of sanitation in it. And if he finds that sanitation is not the chief aim in life, he will also find that he has yet an honourable place in the scheme of things, and his work may become actually more interesting to himself, because more helpful to others, when properly attuned to life as it really is.

If, then, he would learn the true place of sanitation, I will ask him to follow me as I trace some lessons from the history of tropical colonization. Situated in a belt stretching roughly for 30 degrees of latitude north and south of the equator, bathed in sunshine and showers, the tropics are more abundantly provided with life than any other portion of the globe. Vegetation flourishes with a profusion that the inhabitant

of the more temperate regions can hardly imagine, and only by the most strenuous exertions can it be kept from swallowing up the habitations of man. Only [a little] less thriving is animal life, man excepted; for in the tropics the human race does not progress. It is a strange fact, but one beyond dispute, that the tropics have not produced in the last three hundred years, if indeed ever, a single great painter, sculptor, inventor, engineer, or philosopher. Of government and civilisation, as understood by the Greeks, the Romans, and their European descendants for the last two thousand years, there is hardly a trace. Tropical history consists simply of inter-tribal war, barbarity, cruelty, and wanton disregard for property and life.

It would, indeed, not be unfair to assume that this has always been its record; tribe has fought with tribe until one or other has been exterminated, the victor in turn to be overcome by a hardier race from the north. For just as the polar winds are drawn to the tropics by the genial warmth of the sun, so there seems to be a similar flow of the human race. Of tropical invasions by the more virile races from colder zones, the best known is that by the Spanish *conquistadores* who four hundred years ago founded the first world-wide empire. The expense of his wars in the Netherlands, and the hope of glory and riches were forces that acted as powerfully on the King of Spain and on his subjects, and took them to the tropics, as any that drew the Goths on Rome; while to the conquered races the results were even more destructive. In searching for castles of gold, and in mining for precious metals, the Spaniards employed the natives of the West Indies, who "perished out of the islands of the Caribbean Sea with a rapidity which startled the conquerors."[1] Hardly less fatal was the work on the plantations. We understand clearly now that just as the tropical diseases were fatal to the Spaniards, so the European diseases decimated the Caribs: smallpox was one of these.

Lust of gold, sordid greed lubricated by religious fanaticism, utterly destroying a whole nation, casts a lurid light on the Christianity of the leading European people of the sixteenth century. Yet, to the everlasting glory of the Church, the self-sacrificing lives of many of the Fathers are among the noblest records of missionary work, and they never ceased an eloquent remonstrance against this racial murder. At the instance of the Dominicans, led by Bishop Las Casas, a commission came from Spain to enquire into the system of slavery. "They conducted the inquiry in a very dispassionate manner, but, after long deliberation, came to a conclusion most unfavourable to the demands of Las Casas, who insisted on the entire freedom of the natives."[2] All hope of saving the remnant of the race from extinction now seemed to disappear, until it occurred to the bishop to introduce a race which would not only domesticate, but improve in the white man's company. "It struck Las Casas that if negroes could be introduced into the West Indian Islands, the Indians might be left alone; the negroes themselves would have a chance to rise out of their wretchedness, could be made into Christians, and could be saved at the worst from the horrid fate which awaited many of them in their own country;"[3] for those who were brought over as slaves were prisoners of war for whom the alternative was that, if not eaten by their captors, they should be sacrificed on the blood-stained altars of their idols.

[1] *English Seamen in the Sixteenth Century*, J. A. Froude. [2] *Conquest of Mexico*, Prescott, book ii., chap. i.
[3] Froude, *ibid.*

The experiment was a great success at the time, and little did the good bishop dream of the trouble he was making for future generations. Nearly two centuries passed. Spain had shrunk as a world power, Holland and England were the great Colonial powers, with England rapidly taking first place, for she commanded the sea. No longer did colonies pour a stream of crude gold into the mother country; they had long before been stripped bare of that. Their value now consisted of their power to grow spices and other products which could not thrive in colder climates. So merchants established trading stations to barter with the natives; and the native, after his custom, slew the merchant, because he was weak and could easily be killed and spoiled. This led to reprisals, the native had to be taught to respect the white man; his country was conquered. Then the home governments found they were burdened with the charge of governing colonies, for they could not abandon them without inviting a repetition of what they had come to punish.

Few colonies produced sufficient revenue to pay for the necessary civil and military establishments, and still less to send to the treasury at home the contributions which were regarded as the sole justification for their existence. So colonies came to be looked at askance, and were abandoned on any, and even without any, excuse. It was not in the West Indies alone that the local inhabitant would or could not work. Elsewhere the colonist found that the native died if made to work as a slave; money could not induce him to work as a freeman, and to double his pay reduced his output by half. So the colonist came to rely more and more on slaves imported from the few countries where natives were found who could work. Gradually the colonies became more prosperous, became not only self-supporting, but also a source of riches to the motherland.

They had at last justified their existence. Their future seemed assured, when suddenly two great forces strangely affected their even course. One force was new, the other old; one benevolent, the other apparently destructive; one physical, the other spiritual. Neither could be eluded, both were all-pervading.

At last the Christian Church had realized the fatal error she had made in approving of slavery two centuries before, even for so benevolent an object as that of saving the Indians. The Dominicans had never approved of it; even Cortes in his will made the remarkable declaration:[1]

> It has long been a question, whether one can conscientiously hold property in Indian slaves. Since this point has not been determined, I enjoin it on my son Martin and his heirs, that they spare no pains to come to an exact knowledge of the truth; as a matter which deeply concerns the conscience of each of them, no less than mine.

Deep-thinking Christians had "come to an exact knowledge of the truth," and those in Britain had decided that in the British Empire no man should remain a slave—cost what it might. It was a decision from which even now some colonies have not recovered; but none can doubt it was the right one, for even if not fully realized at the time, it is a fact that the best work comes from the free and the willing worker. In Java the brilliant administration of Sir Stamford Raffles, which in five short years turned hopeless bankruptcy into bounding prosperity by giving the native a secure title to the fruits of his labour, proved for all time that the Christian ideal, however impracticable it might

[1] *Conquest of Mexico*, Prescott, book vii, chap. v.

appear, was in truth the real path of progress; and we in British Malaya pride ourselves that our prosperity is in no small degree due to the touch of that vanished hand.

If the spiritual force, in promoting peace and prosperity throughout the world, seemed for a time rather to destroy what had been so laboriously built up, such was not the effect of the great physical force which now appeared; the first throb of the steam engine sent a pulse beat round the world, and stimulated the whole earth to increased life and activity. A hundred years ago the population of England and Europe was gathered into a large number of small villages, with a marketplace in the middle to act as the receiving and distributing centre; the difficulty and cost of transport were too great to permit of produce being taken far from where it was grown. The steam engine has changed all that, and today the wheat of Canada and Russia is sold in London before it is harvested. As the power to manufacture became multiplied by the engine, so arose a greater demand for the raw products of the tropics, and again for markets in which to sell the manufactured goods.

Once again the North hungered for the South, and steamships made communication with distant lands a simple matter; but it was no longer necessary for the northern races to invade the tropics to enjoy their fruits; indeed, for them life there was still very precarious. Just as four hundred years ago both the Spaniard and the Indian suffered in a special degree from diseases to which they were not accustomed, so in later days progress has been greatly retarded by disease, and freer communications have led to national calamities; for by no other name can we call the importation of plague from China to India in 1896 and the steady progress of sleeping sickness across Africa *pari passu* with the step of the white man.

But if these things have to be set against the benefits he confers, there is much on the other side; and no impartial observer can doubt that the end will be gain, although the goal is still far off. It is true that good water supplies had practically abolished cholera; yet in almost every other respect sanitation appeared a failure, especially so in its utter inability to control the disease "which maims as well as kills, and causes more sickness, misery, and death than any other single disease."[1]

The cause of malaria seemed an inexplicable mystery. It was indeed one of the most cunningly hidden of nature's secrets. Men searched the heavens, the earth, and the waters that cover the earth; and if they did not at first find it, the steps by which Laveran, Golgi, and Manson gradually helped to track it down are among the most brilliant in the annals of medicine. They had many difficulties to overcome; malaria was known to be connected with swamps, and to be reduced by drainage and cultivation. Against that they found in some places that flooding a swamp actually improved health, while in other places drainage and turning up the soil produced serious outbreaks of the disease. And yet again, malaria was not found in swamps, but in hills and dry sandy deserts. The whole subject was full of difficulties that seemed to upset every theory; and the only immediate result of his adhesion to, and elaboration of the mosquito malaria hypothesis was to earn for Manson, as he tells us, the suspicion that he was not quite

[1] Govt. of India, Sanitary Resolution, Simla, 23rd May 1914.

right in the head. Certainly no one would have been foolish enough in those days to spend money on eradicating mosquitoes in order to prevent malaria.

When at length the genius of Ross, after long and difficult research, proved the guilt of the mosquito and traced all the stages of the parasite's complicated life in the insect, everyone connected with the tropics realized the importance of the discovery. Our own Government in conjunction with the Royal Society at once sent a Commission to India and Africa; the German Government sent Koch, its greatest medical scientist, to the East Indies; Schools of Tropical Medicine were founded. Tropical research entered on a new path hitherto almost completely neglected, with the result that a series of brilliant discoveries, showing how yellow fever, plague, relapsing fever, sleeping sickness, and other diseases were conveyed from one person to another by insects, lifted the clouds of mystery that had so long hung over tropical diseases—the miasma that had been so fatal to the colonist.

It is in giving the benefits of these discoveries to those amongst whom he lives that the sanitarian finds his opportunity. Yet if he has not already learned that in most places other things have claims on revenue before sanitation, I have written in vain. Without peace, the colony will surely be attacked, lives will be lost; so a rifle brigade is more important than a mosquito brigade; and in India one-third of the revenue is spent on the army in order to preserve peace. Without roads and railways the country's produce cannot be taken to market, the land remains valueless, its proprietor must move or starve. In countries like India, railways and irrigation works come next to the army, for India still largely consists of isolated villages. "If we had a complete record of the fortunes of an Indian village during the last three hundred years, we should probably find that its population has ever and anon been blotted out by some terrible drought."[1] Railways and canals have driven these awful famines from India; in the last thirty years the population has increased by more than fifty millions, who get a better livelihood than their fathers; and the market is no longer local, for India now exports one hundred million pounds sterling worth of goods, her products every year.

Without mosquito brigades, the tropical inhabitant has quite a good chance of surviving: without rifles, railways, and canals he will almost certainly die before reaching the allotted span. In the face of these facts, can the sanitarian still maintain that he has a monopoly of the saving of life?

If we look further into this matter, we will find that human life depends ultimately and entirely on the fruitfulness of the soil—Mother Earth indeed. The sower sows a grain; it multiplies several fold. Some of the increase feeds the soldier, some pays for the railways and canals, and some goes as the tax that supports those employed in what is called "government;" some the peasant keeps to plant in the following season. If the taxes leave him no seed, he dies; if one seed, he lives just as he was. If there remain two or more seeds, he lives better; he becomes more prosperous; the whole country becomes more prosperous; the same taxes do not bear so heavily upon him, old age and poverty are feared less.

[1] *Peoples and Problems of India*, Sir W. T. Holderness, p. 151.

The sanitarian should ever remember he is one who eats the grain he did not plant, and that, if he wastes what is given to him to benefit health, he impoverishes the peasant and the whole country; he is indeed false to his trust. He should ever remember, too, that he is only one of many, each of whom may not agree with him in what he thinks is best for the country. Life has many aspects. On the administrator falls the burden of seeing life as a whole, and it is no light one. That he never fails, he would be the last to claim; but the wiser his expert advisers on sanitary and other matters are, the less often will he err. Of the difficulties of the administrator, one of the greatest tells us something:[1]

> When it became known that the Egyptian Treasury was in possession of a surplus, all the various interests concerned clamoured for the redress of long-standing and often very legitimate grievances. The inhabitant of the country pleaded that his land tax was too high, and pointed with justice to the fall in price of agricultural produce as reason for affording him relief The inhabitant of the town complained of the oppressive nature of the octroi duty. The population in general urged that the price of salt was excessive. The possessor of livestock asked why he should pay a tax for every sheep or goat on his farm. The seller of produce at every market or fair dwelt on the fact that his goods had to be weighed by a Government official, who charged a fee for the Treasury and another fee for himself. Why, again, it was urged, should railway, postal, and telegraph rates be higher in Egypt than elsewhere? Why should a boat passing under a bridge pay a toll, whilst a passenger going over the bridge paid nothing? These and a hundred other arguments and proposals were put forward by the advocates of fiscal reform.
>
> On the other hand, each zealous official, anxious to improve the administration of his own department, hurled in demands for money on a poverty-stricken Treasury. The soldier wanted more troops, and painted in gloomy colours the dangers to which the frontier was exposed by reason of the proximity of the Dervishes. The police officer wanted more policemen to assist in the capture of brigands. The jurist urged that without well-paid judges it was impossible to establish a pure system of justice. The educationalist pointed out with great truth, that unless the sums placed at the disposal of the Department of Public Instruction were greatly increased, the execution of the policy of employing Egyptian rather than European agency in the administration of the country would have to be indefinitely postponed. The soldier, the policeman, the jurist, the director of prisons, and the schoolmaster all joined in asking for construction of expensive buildings. The medical authorities clamoured for hospitals, and pointed out that, without improved sanitation, which was a bottomless financial abyss, there could be no guarantee against epidemic disease. The engineer showed it was false economy not to extend the system of irrigation, to drain the fields, to make roads, and to develop railway communication.
>
> Following on the larger demands came every species of minor proposal. Would it not be an attraction to the tourists, who spent so much money in Egypt, if a theatrical company visited Cairo in the winter? How could this be managed unless the Government gave a subvention to the theatre? Was it not a scandal, now that a civilised power was virtually governing Egypt, that more was not done to protect the ancient monuments of the country from injury? What report would the winter visitors to Egypt make when they returned to Europe, if, in driving to the Pyramids, they were bumped over a road which had not been repaired since the Empress Eugenic drove over it some twenty years previ-

[1] *Modern Egypt*, Cromer, pp. 445 and 453.

> ously? These and scores of other questions were asked in tones of more or less indignant remonstrance, by individuals who realized the desirability of paying attention to some one or other subject in which they were interested, but who had no clear preception of the financial situation considered as a whole. …
>
> The main facts relating to Egyptian finance, when once the thread of the international labyrinth had been found, were, in fact, very simple; when they were understood, they were not uninteresting.
>
> "Nothing," as Lord Milner truly says, "in this strange land is commonplace." The subject surely cannot be devoid of interest when it is remembered that the difference between the magic words surplus and deficit meant whether the Egyptian cultivator was, or was not, to be allowed to reap the results of his labour; whether after supplying the wants of the State, he was to be left with barely enough to keep body and soul together, or whether he was to enjoy some degree of rustic ease; whether he was to be eternally condemned to live in a wretched mud hut, or whether he might have an opportunity given to him of improving his dwelling house; whether he should or should not have water supplied to his fields in due season; whether his disputes with his neighbours should be settled by a judge who decided them on principles of law, or whether, he should be left to the callous caprice of some individual ignorant of law and cognisant only of "baksheesh;" whether, if he were ill, he should be able to go to a well-kept hospital, or whether he should be unable to obtain any better medical assistance than that which could be given to his watchdog or his donkey; whether a school in which something useful could be learnt should be provided for his children, or whether they should be left in the hands of teachers whose highest knowledge consisted in being able to intone a few texts, which they themselves only half understood, from the Koran; whether, if he suffered from mental aberration, he should be properly treated in a well-kept lunatic asylum, or whether he should be chained to a post and undergo the treatment of a wild beast; whether he could travel from one part of the country to another, or communicate with his friends by post or telegraph, at a reasonable or only at a prohibitive cost; in fact, whether he and the ten millions of Egyptians who were like him, were or were not to have a chance afforded to them of taking a few steps upwards on the ladder of moral and material improvement.
>
> This, and much more, is implied when it is stated that the British and Egyptian financiers arrested bankruptcy, turned a deficit into a surplus, relieved taxation, increased the revenue, controlled the expenditure, and raised Egyptian credit to a level only second to that of France and England. All the other reforms which were effected flow from this one fact, that the financial administration of Egypt has been honest, and that the country, being endowed by nature with great recuperative power and being inhabited by an industrious population, responded to the honesty of its rulers. It may be doubted whether in any other country such a remarkable transformation has been made in so short a time.

I invite the sanitarian to ponder deeply on this picture of human existence; to strive to realise what the difference between surplus and deficit really is; and to remember that, since sanitation is primarily a question of ways and means, he must cut his coat according to his cloth. Let the sanitarian grasp the distinction between wisdom and knowledge to which Tennyson alludes in the line:

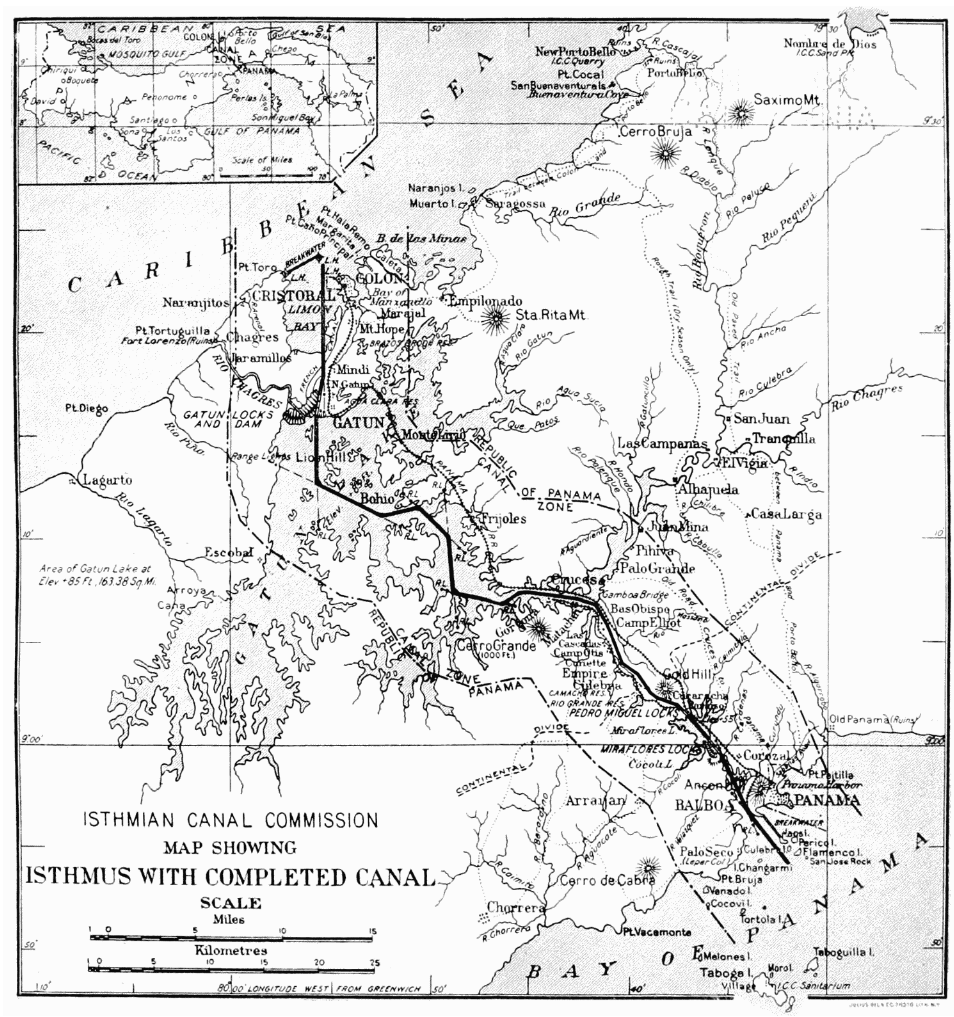
Knowledge comes, but wisdom lingers, …

and the role of the sanitarian in the tropics will be found of unrivalled interest and opportunity.

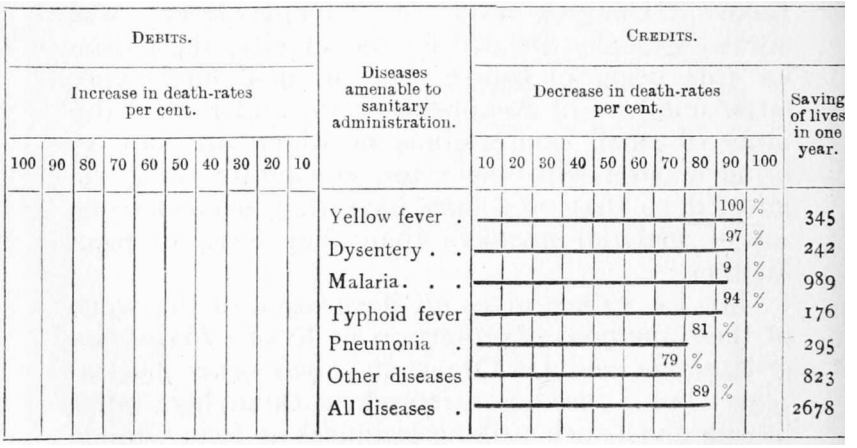
A. Appendix

The original edition of this book does not contain an appendix; the material included in this appendix was moved here from the running text.

A.1 Original map of the Panama Canal zone



A.2 Original version of Figure 15.2



Debits. Increase in death-rates per cent. 100	90	80	70	60	50	40	30	20	10	Diseases amenable to sanitary administration.	Credits. Decrease in death-rates per cent. 10	20	30	40	50	60	70	80	90	100	Saving of lives in one year.
										Yellow fever .									100 %		345
										Dysentery . .									97 %		242
										Malaria. . .									9 %		989
										Typhoid fever									94 %		176
										Pneumonia .								81 %			295
										Other diseases							79 %				823
										All diseases .								89 %			2678

A.3 Panama Sanitary Department reports

In the original edition of the book, these examples of report forms and filed reports occur within the running text of Chapter 13. The reproductions below were prepared from the page scans of that edition.

A.3.1 Weekly malaria report for a single district. Report for the week ending 5th July 1913, for the sanitary district of Gatun. "Emp." means employees, "N.E." means non-employees.

[COPY.]

GATUN, C.Z.,
July 6, 1913.

The Chief Sanitary Officer,
Ancon, C.Z.

SIR,

Report of Population for week ending July 5, 1913.

Place.	Population.		Sent to Hospitals.				Excused for quarters.	
			Malaria.		Total.			
	Emp.	N.E.	Emp.	N.E.	Emp.	N.E.	Malaria.	Total.
Bachelor quarters . .	496	...	...	...	2	1	...	1
Barracks, white . .	900	...	1	...	3	...	...	...
Barracks, black . .	680	...	1	1	3	1	...	...
Married quarters, gold .	190	405	...	...	1	2	1	4
" " silver .	50	85	...	...	...	...	...	...
Spillway . . .	100	200	...	...	...	...	...	...
P.R.R. relocation . .	100	25	...	...	...	...	...	...
P.R.R. cars, Gatun .	85	...	...	...	...	...	...	...
New Gatun . . .	2667	2500	5	2	16	3	...	...
Dredges and tugs . .	200	...	...	...	...	...	...	...
Hospital, police, etc. .	30	...	...	...	...	...	...	...
Monte Lirio . . .	172	136	...	...	...	...	...	...
Frijoles	78	195	...	...	...	...	...	...
Total . .	5748	3546	7	3	25	7	1	5
Not included in above:								
Colon			1	...	3	...	...	...
Mount Hope			...	...	1	...	...	...
Grand totals . . .			8	3	29	7	1	5

Malaria cases from American houses—No., 16.

Very respectfully,

(Sgd.) ALFRED G. FARMER,
District Physician.

Copies to
Chief Sanitary Inspector,
Sanitary Inspector, Gatun
Files.
(By Paraiso, 1 ; Gorgona, 1.)
Total Emps. to Hosp.

A.3.2 Weekly report by the Chief Sanitary Officer. The expression "Excused for Quarters (Excd. for Qrtrs.) means given sick leave without being sent to hospital. "S.C." means Sick Camp.

OFFICE OF THE CHIEF SANITARY OFFICER, ANCON, CANAL ZONE.

Report of Employees sent to Hospitals for week ending July 5, 1913.

Standing, Station, and Camp.	No. Emp.	To Hosp.		This week.	Last week.	Tot. Hosp.	Excd. for Qrtrs.	
		Mal.	Tot.				Malaria.	Total.
				%	%	%		
1 Naos Island	1,056	...	6	·00	·00	·57	...	15
12 Balboa—								
N. Balboa Clrd. Camp	628	3	6				...	...
N. Balboa Spnsh. Cmp.	409	3	7				...	...
N. Balboa E.I. Camp.	50	1	1				...	...
Others	743	...	3				...	10
By Ancon	...	...	2				...	...
	1,830	7	19	·38	·60	1·04	...	10
4 Ancon—								
All camps	888	...	...				...	4
By Balboa	...	...	...				1	1
	888	...	...	·11	·34	·00	1	5
9 Corozal—								
W.I. Camp	509	1	8				...	...
Others	1,474	...	15				...	2
By Balboa	...	2	2				...	...
By Ancon	...	1	2				...	...
By Pedro Miguel	...	...	2				...	...
	1,983	4	29	·20	·60	1·46	...	2
9 Miraflores—								
Miraflores	861	2	6				...	...
Vicinity	768	1	1				...	...
Others	371	...	1				...	...
By Balboa	...	1	2				...	...
	2,000	4	10	·20	·25	·50	...	...
6 Pedro Miguel—								
Tank Camp	41	1	1				...	...
Village	550	1	2				...	...
Jungle	600	1	1				...	...
Waiters' quarters	50	1	1				...	...
Others	912	...	7				...	2
By Miraflores	...	...	2				...	...
	2,153	4	14	·19	·23	·65	...	2
7 Paraiso—								
Hamilton Hill	69	1	1				...	...
Carthagenita, N.V.	245	1	1				...	...
Others	1,428	...	12				...	1
By other stations	...	...	4				...	...
By Pedro Miguel	...	1	5				...	...
	1,742	3	23	·17	·29	1·32	...	1
1 Cucaracha	293	...	5	·00	·00	1·71	...	...
11 Culebra—								
Cowpens	219	1	2				...	...
Rio Grande	846	2	5				1	7
West Culebra	604	3	3				...	1
Others	1,160	...	1				...	7
By Empire	...	...	2				...	...
	2,829	6	13	·25	·21	·46	1	15

Report of Employees sent to Hospitals—continued.

Standing, Station, and Camp.	No. Emp.	To Hosp. Mal.	To Hosp. Tot.	This week. %	Last week. %	Tot. Hosp. %	Excd. for Qrtrs. Malaria.	Excd. for Qrtrs. Total.
6 Empire—								
Old Empire	3,052	5	19				...	5
Cunnette	550	1	2				...	...
Comacho	585	1	1				...	...
Gamboa	210	3	4				...	...
Others	2,360	...	15				...	24
By other stations	...	...	4				...	...
By Gorgona	...	1	1				...	...
	6,757	11	46	·16	·18	·68	...	29
1 Las Cascadas	1,505	...	7				...	5
By other stations	...	...	3				...	...
	1,505	...	10	·00	·00	·66	...	5
3 Bas Obispo—								
Ht. Obispo and Mndnga	490	1	1				...	...
Others	718	...	1				...	3
	1,208	1	2	·08	·25	·17	...	3
2 Matachin—								
Matachin	569	...	2				1	2
Others	781	...	3				...	...
	1,350	...	5	·07	·59	·37	1	2
10 Gorgona—								
Gorgona, native	1,020	1	4				1	5
R.R. cars	51	1	2				...	...
Gorgona, American	360	...	2				...	15
	1,431	2	8	·21	·15	·56	1	20
5 Gatun—								
Barracks, white	900	1	3				...	...
Barracks, black	680	1	3				...	...
Married quarters, gold	190	...	1				1	4
New Gatun	2,667	5	16				...	...
Others	1,311	...	2				...	1
By other stations	...	...	2				...	...
	5,748	7	27	·14	·14	·47	1	5
Cristobal	6,893	4	32	·07	·10	·46	1	18
Panama	...	6	48	...	...	...	1	5

	Disch. from S.C. and Excd. for Qrtrs. Malaria. S.C.	Malaria. Qrs.	Total. S.C.	Total. Qrs.
Toro Point	...	...	1	...
Porto Bello	1	...	3	...
Totals for zone, not including districts of Cristobal, Toro Point, Porto Bello, and Panama	...	5	...	115
Totals (inc. above districts)	1	7	4	138

Toro Point	484	1	3	·21	·00	·62	...	...	1	...
Porto Bello	490	...	2	·20	1·43	·41	1	...	3	...
Totals for zone, not including districts of Cristobal, Toro Point, Porto Bello, and Panama	32,775	49	217	·16	·24	·66	...	5	...	115
Totals (inc. above districts)	40,640	60	302	·17	·28	·74	1	7	4	138

Respectfully submitted,

(Signed) JOHN L. PHILLIPS,
Assistant Chief Sanitary Officer.

A.3.3 Monthly Report of Sanitary Inspectors. A facsimile of a blank report form.

MONTHLY REPORT OF SANITARY INSPECTORS.

Month of ..... 191... ..... C.Z., ... 191...

1. Anti-mosquito work in district. Anopheles.

(*a*) Routine work.

(*b*) New work.

(*c*) Inspection work for adult mosquitoes in buildings.

1. No. of inspections ..... 2. Nos. of houses or cars containing greatest number of adult mosquitoes ..... 3. No. of cases of malarial fever from such houses or cars .....

Comment :

(*d*) General comment on malarial rate and fluctuation during the month.

(*e*) Culex and Stegomyia work. Breeding-places.

(*f*) Containers with larvæ.

(*g*) Amount of oil and larvacide used during the month.

2. General Inspection of District, remarks on.

3. Condition of closets :

(*a*) Pail closets. I.C.C. Native.
1. Number ....
2. Cost of maintenance ....

(*b*) Range closets, No. of .....

(*c*) Public closets.
1. No. and kind .....
.....

(*d*) Pit closets. I.C.C. Native.

(*e*) Frequency of disinfection.
1. I.C.C. range .....
2. I.C.C. pit .....
3. Native pit .....
4. Public .....

3*a*. Fly breeding. Where found.

4. Status of Work Requests.

	No.	Date.	Department.
(*a*) Uncompleted requests	.....	.....	.....
(*b*) Comment on above	.....	.....	.....

5. Quarters and Buildings, I.C.C.

(*a*) General condition of	.....	.....	.....
(*b*) Plumbing	.....	.....	.....
(*c*) Screening, condition of	.....	.....	.....

6. Fumigation and disinfection.

(*a*) No. of .....
(*b*) Kind of materials used .....
(*c*) Quantity of each .....
(*d*) By whom ordered .....
(*e*) Date ordered .....
(*f*) Date completed .....

7. Conditions of Cemeteries.
No. of burials .....

8. Condition of I.C.C. Hotels and Messes.

9. Condition of Public Hotels and Restaurants.

10. Garbage Collection and Disposal.
(*a*) Condition of dumps.
(*b*) Incinerator.
(*c*) Collection.

11. Crude Oil Report :
On hand beginning of month .....
Received during the month .....
Expended during the month .....
On hand end of month .....

12. Larvacide Report :
On hand beginning of month .....
Received during the month .....
Expended during the month .....
On hand end of month .....

13. Force Reports :

Inspectors (Salary) .....
Foremen (Salary) .....
Messengers (Salary) .....
Scavengers .....
Labourers .....

14. Work requests submitted : (Total number of, for the month).

On Q.M.D. Grass ..... Screeening ..... Miscellaneous .....
On Division Engineer .....
On other Departments .....

15. Notices served to abate nuisances, number of .....

16. Arrests, number of ..... Convictions, number of .....

17. Building permits approved, number of .....

18. Pit closets inspected, number of .....

19. Buildings inspected, number of: For screening ..... For mosquitoes ..... For general sanitation ..... For safety .....

20. Stores inspected, number of ..... Restaurants ..... Shops .....

21. Garbage cans emptied, number of: I.C.C. ..... Native .....

22. Closets disinfected, number of: I.C.C. ..... Native .....

23. Houses disinfected, number of ..... Fumigated .....

24. Rat traps in use, number of ..... Rats caught, number of .....

25. Rat poison baits used, number of ..... Rats found dead, number of .....

26. Number of sewer connections made .....

27. Number of mosquitoes destroyed in dwellings : Anopheles ..... Stegomyia ..... Culex .....

28. Number of containers with Stegomyia larvæ found .....

29. Remarks and recommendations.

.....
Sanitary Inspector.

A.3.4 Physician's report on kitchens.

INSPECTION REPORT.

Kitchen at ..... on .....
For the week ending ..... 19....., by Dr .....
..... C.Z., ... 19.....

SIR,

I have the honour to report that this kitchen was inspected on the above date, and conditions found as follows, viz. :—

1. Cleanliness of inside of building, shelving, floors, utensils, etc.
2. Outside disposal of garbage, garbage cans, etc.
3. Presence of flies, amount, where and why.
4. Screening.
5. Condition and state of repair of building and fixtures, drainage, plumbing, etc.
6. Food, uncooked, in kitchen and storeroom ; preparation of food (if you are able to see it).
7. Meat, how handled.
8. Anything else, in your opinion, germane to the subject, included in the resolution.
9. Recommendations.

.....
District Physician.

Table A.1 Malaria hospitalization rates in Juan Grande camp, 1907–1908

1907		Cases (%)	1908		Cases (%)
Jan.	5	1.13	April	4	.49
	12	1.85		11	.76
	19	1.89		18	.76
	26	13.96		25	1.04
Feb.	2	7.76	May	2	.00
	9	6.36		9	.00
	16	9.52		16	.00
	23	5.71		23	.35
March	2	6.29		30	1.04
	9	10.00	June	6	.00
	16	8.82		13	.58
	23	4.70		20	.58
	30	1.18		27	.58
April	6	2.70	July	4	.00
	13	.00		11	4.14
	20	4.50		18	1.18
	27	2.70		25	1.78
May	4	.00	Aug.	1	.00
	11	1.66		8	.55
	18	1.32		15	.00
	25	.93		22	.55
June	1	.46		29	.00
	8	1.86	Sept.	5	.00
	15	.93		12	.00
	22	2.77		19	.00
	29	3.16		26	.00
Average population		232	Average population		268

A.4 Malaria statistics from various rural stations

The figures in the following tables represent hospitalized malaria cases per week, in percent of the local workforce. In the original edition, these tables appeared in the running text of Section 15.8.

Table A.2 Malaria hospitalization rates in Mamei camp, 1907–1908

1907		Cases (%)	1908		Cases (%)
Jan.	5	.88	Jan.	4	.00
	12	.00		11	.83
	19	1.20		18	.00
	26	1.60		25	.00
Feb.	2	6.52	Feb.	1	.83
	9	8.00		8	.00
	16	2.35		15	.00
	23	6.32		22	.00
March	2	12.86		29	.80
	9	3.70	March	7	.00
	16	9.88		14	.49
	23	5.00		21	.97
	30	6.25		28	.00
April	6	1.31	April	4	.00
	13	1.31		11	.00
	20	2.61		18	.00
	27	2.61		25	.97
May	4	1.31	May	2	.49
	11	1.51		9	.00
	18	1.02		16	.00
	25	1.51		23	.00
				30	.00
Average population		173	Average population		170

Table A.3 Malaria hospitalization rates in Porto Bello, 1907 and 1912

1908		Cases (%)	1912		Cases (%)
March	21	13.33	March	23	1.58
	28	10.83		30	1.35
April	4	9.76	April	6	.00
	11	18.97		13	.00
	18	14.62		20	.35
	25	11.94		27	.70
May	2	5.78	May	4	1.06
	9	7.68		11	1.23
	16	9.42		18	2.16
	23	9.76		25	3.78
	30	9.10	June	1	3.51
June	6	8.04		8	1.83
	13	7.00		15	3.85
	20	9.80		22	2.64
	27	6.44		29	2.64
July	4	3.42	July	6	.81
	11	3.25		13	1.62
	18	4.43		20	1.54
	25	4.64		27	2.64
Average population		500	Average population		500

Table A.4 Malaria hospitalization rates in Empire district, 1907 and 1912

Month	Cases (%), 1907	Cases (%), 1912
January	13.75	1.98
February	16.44	1.63
March	11.95	1.78
April	6.79	.81
May	5.28	.53
June	9.49	1.80
July	12.23	1.99
Aug.	14.03	1.76
September	8.09	.93
October	4.35	.73
November	3.45	.87
December	3.22	.76
Average population	3,000	6,100