MODERN TROPICAL HYGIENE.

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Although the discoveries of Ross and others of how tropical diseases were spread by various vectors gave to men a new hope that these diseases could be prevented, progress was slow until a new technique based on further researches was devised. Indeed, for a generation extraordinarily little progress was made in what I might call "modern tropical hygiene." So much so that shortly before his death in 1933 Sir Walter Fletcher said to me: "There has been a scandalous neglect to apply the knowledge which we have acquired."

MALARIA.

What are the facts? Perhaps what I shall describe about the prevention of malaria and the prevention of sleeping sickness will give some idea both of triumph and failure. Malaria is a disease to be found in every part of the tropical and sub-tropical regions, and in many parts of the temperate regions. It kills, and maims, and incapacitates, and causes more economic loss than perhaps any other disease; there was every inducement for men to press on with its prevention.

Led by Koch, the profession for the most part thought that, if all cases of malaria were treated with quinine they would be cured, that they would cease to infect mosquitoes and that the disease would die out. We know now, after many attempts, that the parasite reservoir in man cannot be destroyed by quinine alone; and so far with no drugs have we truly prevented malaria. Perhaps alone in his generation Ross had a clearer idea of how the disease could be prevented by striking at the mosquito and breaking the malarial cycle at that particular link. It is true that he believed it possible only to do this in towns, but he urged the need for more research on various species of mosquitoes if practical use was to be made of the discovery. For rural areas he thought that personal prevention such as the use of the mosquito net, the use of mosquito boots, the taking of quinine was all that could be attempted.

Early efforts at prevention. Early in 1901 I was stationed in a small town on the Malay Peninsula and was Health Officer of an adjacent port. After making a survey and mapping out the distribution of the malaria and the mosquitoes I induced the Government to drain the two places. The resulting disappearance of malaria was far beyond our greatest expectation. It actually saved the port from being closed: orders to close it had already been given. This was the beginning of a long series of large-scale experimental researches and to the reclamation subsequently of much previously malarial land.

In 1904 the Government, on my recommendation, drained an extensive rural area, some 50 square miles, again with the most striking success. Not only did we drive out malaria in this way but we were able in a short time to formulate simple rules which the layman could understand and act on; and we learnt how to choose a healthy site out of reach of the mosquito *A. umbrosus* which was carrying the malaria. In a letter to me Ross said, "I have never dared to moot the idea of mosquito reduction in rural areas." He was delighted to hear it had been done successfully.

A new problem. In 1909 I realised there was a new problem, that of a mosquito which lived in fast running water in hill streams, one which carried malaria so effectively that if we attempted to build up a labour force of 400 or 500 the death rate often reached 200 and 300 per thousand per annum. Our first effort against this mosquito was to put all streams and springs within a radius of half a mile of inhabited buildings in pipes under ground, so as to deprive the mosquito of its breeding places. This method proved successful and is used extensively in towns in Malaya.

At the same time, as a result of the previous eight years' work, and especially of four years' work on the study of the 13 species of anopheles in some valleys in hill land, I had come to the conclusion that it might be possible to strike at the dangerous species of anopheles by simpler methods than we had yet employed. When the rubber planter felled the jungle to plant his rubber trees, he might or might not fell the jungle in the valleys, which had little or no agricultural value compared with the higher land. What happened to the valleys was therefore of little concern to him. But what he did or refrained from doing to the valleys was of vital importance to their insect inhabitants. If he felled the jungle he drove out some species of anopheles and some others took their place. If the bottom of the valley was a morass with stagnant or semi-stagnant dark peaty water the species of anopheles was different from when there was a fast running stream of clear sunlit water. It would take too long to describe all the changes that might occur in a valley in the course of a year or even a few months, and the procession of species that followed the changes. In time I learned that the changes in the species were not fortuitous, but that they followed the Law. No single species, either dangerous or harmless could live through the whole gamut of changes that might occur in a valley. One day it occurred to me that the procession of species of anopheles might be arrested and fixed at any stage which we desired, and that in fact we could say to some species "Come" and to others "Go," and that by doing so we might drive out malaria at little or no cost. So in the year 1909 was born the method, now so extensively used under the name given to it by the Dutch, "*Species Sanitation*."

Species sanitation. This method of control by natural means for any country involves research; we have to discover what species of mosquitoes carry malaria and what do not. Fortunately in most places perhaps only one species of anopheles in a dozen is of importance. Each species has its own peculiar habits, and by making the environment of the breeding place uncongenial we hope to drive out the dangerous species. For example, if a mosquito likes a quiet life in a pool we cut a drain through the pool and cause a current of water; if it requires grass in a drain we remove the weeds; if the mosquito likes shade we fell the jungle and let in the sunshine; if the mosquito loves sunshine and sparkling water we preserve the jungle or grow a hedge over the breeding place and so drive it out. If a mosquito breeds only in water of a certain salinity, by raising or lowering the salinity we can often drive it out and so free the locality from malaria. By tide gates it is easy to exclude or admit sea water to these coastal areas which are often intensely malarial in the tropics. Even a bar of soap or people washing their clothes in a stream will make that water uncongenial to a dangerous mosquito; for the action of the soap has a far-reaching effect on the algal life of the water, and the dangerous anopheles require special algal food. In addition to these methods we invented poisons which we applied to the streams, sometimes oils and sometimes arsenical preparations. One of the latest methods has been to put across a stream a dam incorporating syphons or tippers, so converting a slow and continuous current into

violent intermittent rushes of water. It was discovered, too, that most rice fields nourished only the harmless species, and that where there was malaria it was sometimes possible to control it by intermittent flooding or by special treatment of the weeds in the fallow season.

Large-scale research and reclamation. All this demanded years of work. It was large-scale research, growing into team work between the medical officer, the entomologist and the engineer, all co-operating with the agriculturalist. It has been a great triumph although it was something far removed from the ordinary practice of medicine. The Dutch in the East Indies were the first to realise what was being done in Malaya. By 1913 they began their magnificent research and practical work. In 1914 the Rockefeller Foundation of the United States of America, after sending two men to learn the Malayan methods, opened a school for teaching people in the United States, and later spread the knowledge to Europe and other parts of the world. In 1924 I visited India for the first time to begin anti-malarial work. This was enthusiastically taken up by Dr. G. C. Ramsay, now Deputy Director of the Ross Institute, in India. The founding of the Ross Institute in London made it possible to speed up the prevention of malaria in many lands, and the Institute is now responsible for the control of malaria in hundreds of thousands of acres of tea estates in India and Ceylon, on copper mines in Africa, on gold, lead and other mines as well as estates and other commercial concerns in many parts of the world.

It is quite impossible to give any full notion of the saving of life that is going on now as a result of these measures, for at an early stage we found that the prevention of malaria led also to the reduction of the death rate from other diseases as the following table shows:—

DEATHS IN THE TOWNS OF KLANG AND PORT SWETTENHAM.

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

Anti-malarial work was begun in 1901.

The control of malaria and yellow fever in Panama, begun in 1904, made it possible to carry through that great engineering work, the construction of the Panama Canal, which the French failed to do because they were ignorant of how malaria and yellow fever were carried. Up to 1911 the City of Singapore had been stricken annually by a great wave of malaria. The work which was begun then has been carried on continuously, and there is little reason to doubt that but for that work there would have been a hundred thousand more deaths than actually occurred in the last 25 years. It certainly would have been quite impossible to gather together the 7,000 or 8,000 labourers required to build the Naval Base if the knowledge given to us by Manson and Ross had not been applied by the Admiralty to their problems of sanitation.

Economic effects. But apart from questions of death rates the control of malaria has had an economic effect of vast, almost incalculable magnitude. Addressing a meeting of the Federal Council in 1926 His Excellency the Governor

said: "It must be obvious to all who are acquainted with the conditions that prevailed in the Malay Peninsula during the concluding decades of the nineteenth and the opening years of the present century that developments such as the rubber industry, which in so short a space of time has spread over so enormous an area, would have been totally impossible unless the danger of malarial infection had first been successfully combated." Between 1920 and 1930 the British Empire produced 75 per cent. of the world's rubber and America consumed some 300,000 tons a year. It must be obvious, therefore, that the prevention of malaria, which enabled Britain to produce so much rubber, for many years helped to maintain the value of sterling in the sterling-dollar exchange and has made no mean contribution to the payment of the British war debt to America.

SLEEPING SICKNESS.

Turning now to the prevention of sleeping sickness, and trypanosomiasis in man, we are concerned with a disease which, although not world wide in extent like malaria, is of profound importance to the economics of the world. In the preface to the late Mr. Swynnerton's book, "The Tsetse Flies of East Africa," the then Mr. Ormsby-Gore, who was Secretary of State for the Colonies, writes: "As is well known there is scarcely a question of greater importance for the future development and well-being of the British and other territories in that part of the world. The future prosperity of considerable tracts of Africa depends on whether it will be found possible with the aid of science to devise means by which they can be inhabited by man and his domestic animals without risk of infection by human or animal trypanosomiasis." The area stricken is, in fact, a band reaching from the Atlantic to the Indian Ocean, 2,000 miles wide, and affecting the Colonies of France, Portugal, Britain and Belgium with outlyers in Arabia, Abyssinia and the Sudan.

Parasitic reservoirs. The story of the control of sleeping sickness and trypanosomiasis is in some ways similar to that of malaria; but there is in one respect a great difference. The reservoir of malaria is man; the cycle is simply man, mosquito and man and so on. The great reservoir of trypanosomiasis is the wild animal, mainly the ungulate; and the cycle is animal, tsetse, animal, with the infection of man as an accident, although indeed a fatal accident, to the parasite and to man. Many of the wild animals have a high degree of immunity to the fly, but to man and most of his domestic animals the disease has meant death until the drugs were discovered which could cure it. It is, of course, not possible to cure all the wild animals by means of drugs. It might have been feasible to shoot off most of them, but it is doubtful if this would, in fact, have been effective in stopping trypanosomiasis. Fortunately it was realised after intensive study by the late Mr. Swynnerton, and by the team which he led, that man and his animals might be protected by measures which were less drastic than shooting all the game in order to kill the reservoir, or burning all of the trees, bush and grass to kill the tsetse fly carrier. He had the vision to realise that simpler measures might be effective, might be more easily applied, and would assist in preserving the land from the already too destructive agents of soil erosion. Of course he realised that these new methods could only be evolved as the result of research on many subjects from many different aspects of the problem. Here are a few of these researches.

Species sanitation. There are 21 species of tsetse fly in Africa. Each had to be studied separately; their distribution, habits, movements, senses, requirements in food, shelter, breeding places. The survey had to include the domestic animals

in relation both to the fly and to trypanosomiasis; (fortunately some species of tsetse were found to be practically harmless); the wild animals as food for the fly and as host for the trypanosome; the types of vegetation, whether dense wet jungle, lighter or shady jungle, or bare almost shadeless thorn bush in relation to each species of fly. These are but some of the aspects of the trypanosome and tsetse problems; there were also many administrative and tribal problems.

Since 1921 when Mr. Swynnerton began his work in Tanganyika great progress has been made by observation and experiment, as we see from his volume published in 1936. He tells us that "the attack on the problem" had to be "by intensive research conducted with large scale experimental attack in the field—or so-called experimental reclamation." So he made land surveys, noting all the factors that might affect the fly, and he soon saw the value of air survey in demarcating the various types of vegetation. Some areas free from tsetse could not be grazed because they were surrounded by a tsetse belt; so he made fly-free corridors by which cattle could pass across the tsetse belt from one grazing area to another without contracting the disease. In this way he enormously increased the grazing area of certain tribes and received their gratitude and help. He noted that in the dry season the tsetses congregated around water holes frequented by the animals and that when the wet season came the flies spread along lines of forest which sometimes followed a stream and sometimes stretched away from it. By making clearings across these belts of forest he has been able to prevent the spread of the fly, and then by trapping the fly in its dry season haunts he has been able in some places to exterminate it. Then again clearings have been made to isolate a block of infested bush and in this the flies are exterminated by various methods. He sometimes stopped the annual grass burning, for he discovered that if the grass were not burned a denser vegetation would grow up which of itself was sufficient in many places to reduce the number of flies. In other places he stopped the usual grass burning until the vegetation had become very dense; then he fired it and obtained a hotter fire which was more effective in the destruction of the tsetse breeding places. In some places he employed discriminative site selection; the people were settled on small areas containing flies which, however, disappeared as soon as the people had settled and cultivated the land. In some places he controlled the amount of cattle grazing and the kind of cultivation. Sometimes he destroyed the breeding places of the flies and sometimes the places to which they went to feed. These might not always be the same. He invented many different kinds of traps and used them with greater or less success. Some of the African tribes have already seen the value of this work and are working enthusiastically on the tsetse control at the present moment. Hundreds of square miles have already been reclaimed, and although the fly has spread in some areas there is little doubt of the ultimate success for work on the lines already planned by Swynnerton before his death.

PLAGUE.

Plague is a disease with which medical men in this country are perhaps more familiar than they are with either malaria or sleeping sickness. It is even more widely spread than malaria, but happily does not take such a heavy toll of human life, except occasionally and in special areas; for once again, the disease in man is only an accident. As Colonel Glen Liston has said, it is essentially a disease of the rodent, which is the reservoir of the disease.

The problem in many places is essentially that of isolating man from the rat, and excluding the rat from contact with man's home and from his food stuffs.

By making houses, ports and ships and warehouses rat-proof great success has, in many places, been achieved in the control of plague. But again it has been found that the spread of the disease is largely dependent on the species of the rodent and the species of the flea, and that a knowledge of these facts has been required if the control of the disease is to be economically carried out.

THE FUTURE.

From what I have said it must be clear that these sanitary problems, human or animal, do not stand alone. The control of malaria, of trypanosomiasis in man, of trypanosomiasis in cattle are linked up with forestry and agriculture. Already vast areas in Africa, Asia and America have been ruined by the agriculturalist through ignorance of the danger of soil erosion. The great dust bowl of the United States cannot yet have been forgotten. It would be unwise to choose a method for the control of the tsetse which would increase the danger of soil erosion. It would be unwise to employ a method of malaria control which would increase the danger of trypanosomiasis, or which would deprive the agriculturalist of the use of water which is so essential for his crops. In other words, all these problems must be considered together. The administrator, the medical officer, the veterinary officer, the engineer, the forest officer, the agricultural officer, and the agriculturalist and the tribes who own their land must co-operate. There is no reason, however, to be pessimistic. Research did not end with the discoveries of Laveran, Manson, Ross, Bruce and the other pioneers of tropical medicine. These have been but the prelude to further discoveries, and the men who have been most active in the research and large-scale experiment for the control of malaria and trypanosomiasis are convinced that there are many weak points in the armour of their foes and that their enemies will surely be overcome by sustained attack.

In each of these diseases control has been obtained by breaking a link between a reservoir of parasites and the man to be infected. The reservoir may be man or a wild or domestic animal, and the link a mosquito, a tsetse or a flea.

The aim of control has always been to disturb the essential relationship between reservoir, vector and man in the cheapest way without otherwise damaging man and his surroundings. We have seen how beautifully this can be done when detailed knowledge is acquired of these essential relationships. And some of us can recall how the problems were declared insoluble by those who did not grasp the full meaning of the work of Manson and Ross.