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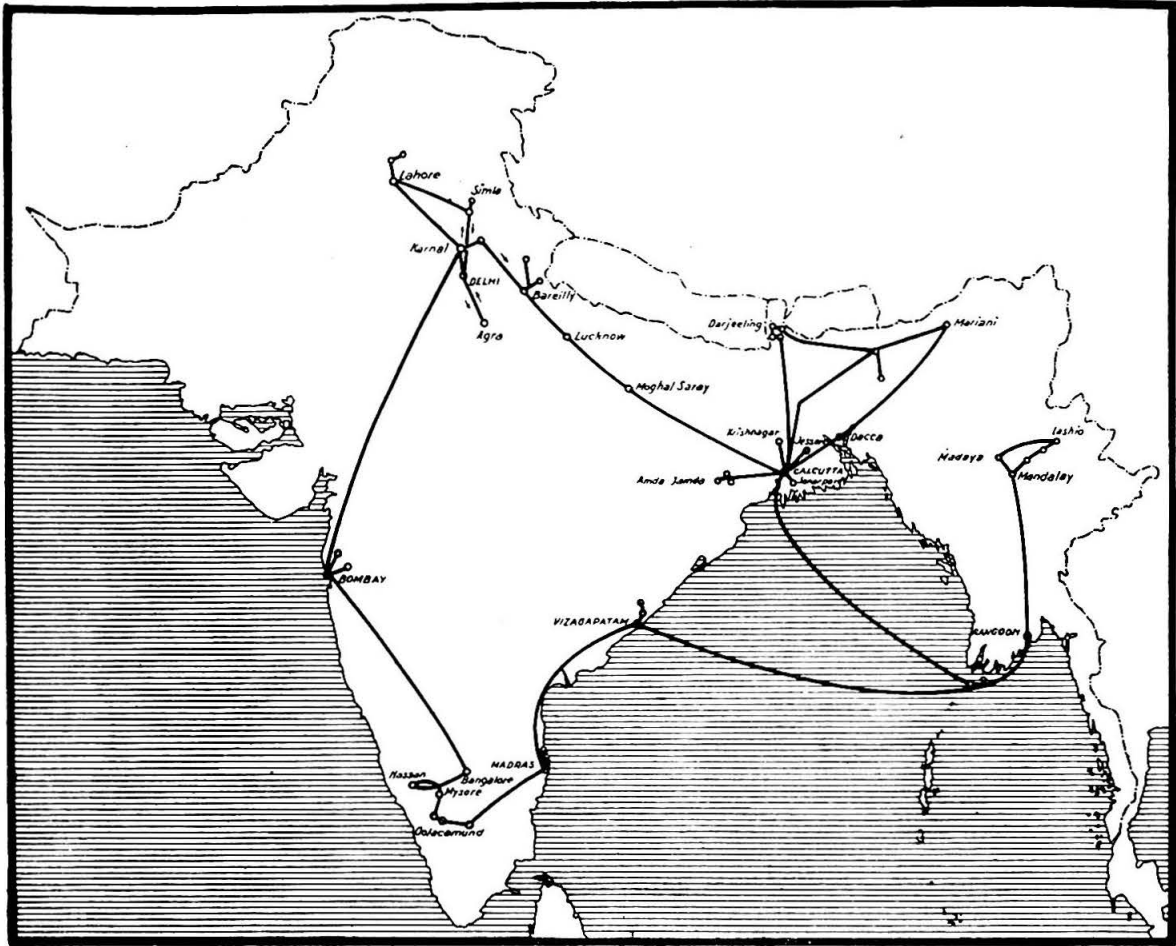
MALARIA COMMISSION

**Report of the Malaria Commission  
on its Study Tour in India**

(August 23rd to December 28th, 1929.)

Series of League of Nations Publications

III. HEALTH  
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### ITINERARY OF THE STUDY TOUR.

Aug. 1929

- 23 Arrive Bombay.
- 24 Visit Dock Area with Port Health Officer.
- 25 Visit Kopri.
- 26 Visit St. George's Hospital and surrounding district.
- 27 Visit North of Bombay Island to see Monsoon conditions.
- 28 Visit Back Bay Reclamation Area.
- 29 Depart for Karnal.
- 30 Arrive Ross Field Experimental Station for Malaria, Karnal.
- 31 Karnal. Statement on Malaria Problem in India, by Col. Christophers.

Sept.

- 1 } Local excursion to investigate Malarial conditions.
- 2 }
- 3 Study Indian Anophelines, adults and larvæ. Depart for Lahore.
- 4 Arrive Lahore.
- 5 Exposition on "Malaria in Punjab with Special Reference to Epidemic Malaria" by Col. Gill. Inspect Epidemiological Bureau and Hygiene Museum. Visit environs of Lahore.
- 6 Visit Lahore City. Exposition on "Water-logging Problem and Anti-water-logging Measures" by Mr. Smith. Visit Lahore Cantonments (Mian Mir).
- 7 Depart for Khanki, Gujranwala District. Inspect Headworks, Lower Chenab Canal.
- 8 Inspect Chankanwali Reclamation Farm and anti-water-logging measures.
- 9 Visit Aik Nallah, Sambrial, Mir Ali and Upper Chenab Canal.
- 10 Visit Chankanwali Reclamation Farm and neighbouring villages. Return to Khanki.
- 11 } Visit Kathala, Gujrat District to study conditions in a flooded riverain area
- 12 } and an area in which an epidemic is expected to occur shortly.
- 13 }
- 14 Depart Kathala. Visit Gujranwala Pumping Station. Arrive Lahore.
- 15 Depart for Kasauli.
- 16 } Arrive Kasauli. Visit Central Malaria Bureau and Headquarters, Malaria
- 17 } Survey of India. Study Collections and work on Anophelines, adults and larvæ.
- 18 Excursion to collect larvae at Hart's Pool.
- 19 Visit Malaria Treatment Centre. Military Food Laboratory and Enteric Convalescent Depot.
- 20 Visit Pasteur Institute of India.
- 21 Visit Central Research Institute.
- 22 Depart for Simla. Arrive Simla.
- 24 Return to Kasauli.
- 25 Depart for Delhi.
- 26 Arrive Delhi. Address on Malaria in Delhi by Major Sinton. Visit Delhi City.
- 27 Visit Delhi Fort and Bela.
- 28 Visit Notified Area, Civil Lines. Leave Delhi for Agra.
- 29 Visit Agra Fort, Taj Mahal, Akhbar's Tomb, Fatehpur Sikri. The latter is the remains of a city ruined by malaria. Depart for Delhi.
- 30 Arrive Delhi. Visit Notified Area, Civil Lines.

Oct.

- 1 } Visit New Delhi.
- 2 }
- 3 } Visit rural areas of Delhi Province.
- 4 }

Oct.

- 5 Visit area surrounding Delhi Gaol. See Feroz Shah Katta and Purana Qila. Depart for Karnal. Arrive Karnal.
- 6, 7, 8 }
  - 9 See the Malaria Class at Work. Visit surrounding villages and do spleen and blood examinations. Demonstration on the use of paris green by Dr. Williams.
  - 10 } Lectures on "The Treatment of Malaria" by Major Sinton.
  - 11 }
  - 12 }
- 13 Depart for Saharanpur. See effects of irrigation, wet cultivation and results of anti-malarial measures. Depart for Kathgodam.
- 14 } Arrive Kathgodam. Visit Terai and Bhabar.
- 15 } The former very malarious. See effects of cultivation; water-logging, and irrigation; cultivation of leguminous crops (clover); racial immunity; proposed cinchona cultivation.
- 16 }
- 17 Arrive Banbassa. Inspect Head Works of Sarda Canal; intensely malarious area; aggregation of labour; anti-malaria measures.
- 18 Depart for Lucknow.
- 19 Arrive Lucknow.
- 20 } Interview with Administrative Health Officers. Study Provincial Malaria Reports and Statistics. Investigate canal irrigation in relation to malaria; tank problem; flushing scheme; anti-malaria measures; village aid.
- 21 }
- 22 Arrive Moghul Serai. Railway in relation to malaria. Depart for Calcutta.
- 23 Arrive Calcutta.
- 24 Visit Calcutta School of Tropical Medicine and Hygiene including Bengal Malaria Research Laboratory.
- 25 Visit Calcutta School of Tropical Medicine. Discussion with Col. Knowles and Mr. Senior-White on "Parasitology of World Malaria". Visit Co-operative anti-malaria Societies.
- 26 Visit villages in Sonarpur area. Visit Salt Water Lake area and Buderhati. Discussion with Dr. Bentley on "Malaria in Bengal". Conference of Co-operative Anti-malaria Societies.
- 27 Arrive Tarpassa. See flooded non-malarious area. Return to Calcutta.
- 28 Arrive Calcutta. Depart for Singhbhum area with Mr. Senior-White.
- 29 } Study malaria control work at Dangoaposi, Bara Janda, and Noamundi.
- 30 } Leave for Calcutta.
- 31 Arrive Calcutta. Depart for Jessore.

Nov.

- 1 Visit Jessore which is an intensely malarious area with numerous "decaying" rivers. Return to Calcutta.
- 2 Depart Calcutta. Visit Birnagar and leave for Berhampore.
- 3 Visit Mushidabad, Jiaganj and Bhagawangola. Visit Gobra Nala area. Leave Berhampore for Krishnagar.
- 4 Inspect hyper-endemic villages near Krishnagar. Leave Calcutta for Siliguri.

Nov.

- 5 Arrive Siliguri. Inspect local malarial conditions with Capt. Chalam. Motor to Darjeeling stopping at Sukna en route.
- 6 Spend day in Darjeeling.
- 7 Leave Darjeeling. Arrive Siliguri. Investigate Terai conditions.
- 8 Continue investigation of Terai conditions. Proceed via Phulbarighat to Sylee.
- 9 Inspect anti-malaria work in Tea Gardens at Menglass.
- 10 Depart Menglass for Gauhati.
- 11 Arrive Gauhati. Inspect Kala-azar Commission Field Laboratory. Visit Government Silk Emporium. Demonstration of main indigenous village industry in Assam.
- 12 Visit Dudnai area to see Kala-azar Treatment Centres and to see villages where spleen rate is due to Kala-azar and not to malaria. Depart for Mariana.
- 13 Arrive Mariana. Proceed to Jorhat. Inspect Scientific Station of Tea Association, Toklai. Visit Melling Tea Garden to inspect labour conditions.
- 14 Visit Kotalguri Tea Garden showing low malaria incidence. Visit Naganijan Tea Garden showing high malaria incidence. Depart for Mariana en route for Shillong or Cachar.
- 15 Party (a) Arrive Shillong.  
Party (b) Arrive at Cachar to inspect malaria control work carried out by Dr. Ramsay in Tea Garden area.
- 16 Party (a) Shillong,  
Party (b) Cachar.
- 17 Party (a) Leave Shillong for Calcutta.  
Party (b) Leave Cachar for Calcutta.
- 18 All members arrive Calcutta.
- 19 Depart for Rangoon.
- 22 Arrive Rangoon. Discuss Malaria Problem in Burma with Director of Public Health, Burma. Visit Harcourt Butler Institute. Depart for Mandalay.
- 23 Arrive Mandalay. Visit malarious villages.
- 24 Depart Mandalay and arrive Maymyo Proceed to Sakantha.
- 25 Depart Sakantha and arrive Hsipaw. Study malaria conditions at Hsipaw. Depart for Lashio.
- 26 Study malaria conditions at Lashio.
- 27 Depart Lashio. Arrive Maymyo.
- 28 Depart Maymyo. Arrive Madaya. Investigate malarial conditions at Madaya. Return to Mandalay en route for Rangoon.
- 29 Arrive Rangoon.
- 30 Embark for Vizagapatam.

Dec.

- 1 }  
2 } En route for Vizagapatam.  
3 }

Déc.

4. Arrive Vizagapatam. Inspect malaria control measures at Harbour Works, Vizagapatam.
  - 5 } Depart for Rayagada via Parvatipurram.
  - 6 } Malaria Control Work. Depart for Satikona.
  - 7 } Arrive Satikona. Inspect area under malaria control and compare with
  - 8 } uncontrolled area. Leave Satikona for Salur. Visit hyper-endemic area at Koraput.
  - 9 Depart Koraput and arrive Salur.
  - 10 Depart Salur and arrive Waltair. Depart for Madras.
  - 11 Arrive Madras City.
  - 12 Visit Ennore. Inspect King Institute, Guindy. Depart for Errode.
  - 13 } Arrive Errode. Inspect Laboratory at Mettur and return to Errode.
  - 14 }
  - 15 Depart Errode. Arrive Coonoor. Visit Pasteur Institute, Coonoor, and Nutritional Diseases Enquiry.
  - 16 Visit Ootacamund and Nadvattam. Inspect cinchona cultivation.
  - 17 Depart Ootacamund. Arrive Mysore.
  - 18 } Halt at Mysore.
  - 19 }
  - 20 Depart for Bombay.
  - 21 En route for Bombay.
  - 22 Arrive Bombay.
  - 23 and subsequent days see Bombay in dry season, and study anti-malarial operations.
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*Prepared for the Malaria Commission of the League of Nations, on the occasion of its Study Tour in India (August 23rd-December 28th, 1929) by Brevet-Colonel S. R. CHRISTOPHERS, C.I.E., O.B.E., F.R.S., I.M.S.*

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[Mian Mir, Dinajpur, Saharanpur, Nagina, Kosi, Andamans, Ennur, Madras, Delhi (early phase), Lumding, Pasighat, Singanama and Pagara, Meenglas, Singaran and Toposi, Jangipur, Banka Valley, Sara Bridge, Sarda Canal, Nalbari, Manhapur, Bombay, Colaba, Vizagapatam, Delhi (late stage), the Punjab, Coorg, Indian Railways, Sukkur (Sind).]

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NOTE.

*In presenting their Report, the members of the Malaria Commission take pleasure in prefacing it by the highly valuable and interesting Note on Malaria Research and Prevention in India kindly prepared by Brevet-Colonel S. R. CHRISTOPHERS, C.I.E., O.B.E., F.R.S., I.M.S.*

*They feel that, if the reader first acquaints himself with the historical matter contained in this survey, he will be able to bring a clearer understanding to the perusal of their own report, which begins on page 27 of the present publication.*

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NOTE ON MALARIA RESEARCH AND PREVENTION IN INDIA.

PREPARED FOR THE MALARIA COMMISSION OF THE LEAGUE OF NATIONS, ON THE  
OCCASION OF ITS STUDY TOUR IN INDIA (AUGUST 23RD-DECEMBER 28TH, 1929)  
BY BREVET-COLONEL S. R. CHRISTOPHERS, C.I.E., O.B.E., F.R.S., I.M.S.

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INTRODUCTION.

Dr. Mackenzie, then Secretary to the Malaria Commission, when I met him in London, asked me if I would make a statement to the Commission in regard to malaria in India. I was at first somewhat hesitant to take upon myself a function which seemed somewhat uncalled for. But, on considering the matter, I thought that it might perhaps be useful to the Commission if I were to prepare a resumé giving a brief history of malaria research and prevention in India, including a list of various operations carried out from time to time in India, so that on the tour some of the institutions and places visited might be seen in perspective in relation to the whole. A bibliography of works on malaria in India, prepared by Major J. A. Sinton, V.C., O.B.E., I.M.S., Director of the Malaria Survey of India, is now in the press and is expected to be published very shortly as the first number of a new series, "Records of the Malaria Survey of India". This will be in the hands of the Commission before it leaves and should facilitate all references to literature.

## HISTORY OF MALARIA RESEARCH IN INDIA.

### EARLY WORK.

Though one is apt to pay little attention now to work done on malaria prior to the epoch-making discovery by Ross, a brief mention may be made of some work in India which preceded this discovery. I refer to the work on cinchona and quinine.

India took a very active part in the early botanical and other work connected with the introduction and cultivation of cinchona and manufacture of quinine. The first preparation of cinchona to be manufactured on a large scale was one consisting of the total alkaloids known as "cinchona febrifuge", a preparation which in its modern form has many advocates for use in popular distribution on account of its cheapness. An important landmark was reached when, in 1887, an entirely new process for manufacturing pure quinine sulphate was discovered at the Sikkim plantation and, the details being published by Government, the manufacture of quinine was much cheapened throughout the world. Associated with this early pioneer work are the names of Markham, Spence, Cross, McIvor, Anderson and others. An early bibliography on the subject is that given by Waring, who was a surgeon in the Indian Army, in his *Bibliotheca Therapeutica* (New Sydenham Society, Vol. 78).

Another subject for which early Indian work is notable are studies on the spleen rate. Dempster, as early as 1845, employed this method in a perfectly unmistakable form in the mapping of malaria in the Eastern Jumna Canal area, on the health of which he was reporting. Major Sinton, Director of the Malaria Survey of India, has been able to obtain early copies of Dempster's works, and these are being re-published with Dempster's original maps along with certain other reports difficult of access at present which it seems advisable, if only for interest's sake, to make available for reference.

Whilst, however, this early work is interesting, I must not devote too much time to it and must pass on to what is practically the starting-point of malaria research in its present form. I refer to the discovery of Sir Ronald Ross of the mosquito cycle in malaria, for the *locus* of which discovery India was fortunate to be chosen.

### WORK 1900-1908.

It is not necessary here to refer in any detail to Ross's discovery of the mosquito cycle, the facts regarding which are now world known. It is chiefly the effects of this discovery, as these were clearly displayed in India, that most concern us. In India, as all over the world, Ross's work was followed by a great increase in the interest taken in malaria and other tropical diseases. In 1900, shortly after the results of this work were known, the Royal Society's Malaria Commission visited India and spent a year investigating malaria in this country from the new standpoint. The visit of the Commission brought knowledge of technique of staining and examining malaria parasites

and the methods of malaria study generally to many already interested in this subject. Endemic studies from the new point of view were for the first time carried out. Experiments to determine the carrying power of the different common anophelines and the discovery of the differential breeding habits and the biological differentiation of these species as larvæ and as adults were among many results obtained. Other workers, however, even before this, notably Giles and James, had taken up the study of mosquitoes, and the systematic work of Giles on mosquitoes generally and of James and Liston on the Indian anophelines were among the earliest pioneer work of this kind in the world.

In this period were laid down many points in technique and so on that have almost unconsciously been taken into the modern worker's repertoire. The general life history of the different species of anophelids, where these were to be found, the methods of collection and identification and much else was learnt. Among names other than those already mentioned associated with what may be called this early Indian school, are those of Adie, Donovan, Liston, Turkhud, Cogill, Patton and others.

#### WORK 1908-1920.

In 1908 much consternation was caused in the planting districts of North-East India, and especially in the Duars, by the high mortality from blackwater fever. This led, at the instance of Col. Leslie, I.M.S., Sanitary Commissioner with the Government of India, to an investigation under Christophers and Bentley of the aspects of the malaria problem in this part of the country. This survey was followed by a survey of Bombay City by Bentley and of the Punjab, following the great epidemic of 1908, by Christophers. The multiplicity of the aspects under which malaria was found to occur and the very varied possibilities as to methods of combating it under these conditions led Col. Leslie to inaugurate a conference on Malaria, in which His Excellency the Viceroy greatly interested himself, and which is known as The Imperial Malaria Conference (1909).

Here, and in subsequent meetings of delegates, was laid down the beginnings of an organisation for the study and prevention of malaria in India.

The Organisation consisted of provincial and a central organisation. In each province was formed a Provincial Malaria Committee which delegated each year one of its members, usually the malaria officer as explained below, to attend a meeting of a General Committee. The most important development in regard to this provincial organisation was that in almost every province a trained relatively senior research officer was appointed as the provincial malaria officer whose business it was to investigate and generally further research and preventive measures in his province. In this period were carried out surveys of large tracts in India, the work of Bentley, Fry, Graham, Kendrick, Adie, Perry, Gill, Ross, Horne and others collectively for the first time giving some idea of the real malaria problem in India.

The Central Organisation consisted of a Central Scientific Committee which met and considered the requirements of India in respect to malaria research and prevention. Suggested lines of investigation as to data most urgently required and so on were drawn up and published in the journal *Paludism* that was then started. A Malaria Bureau, then

a new idea, was constituted, the functions of which were much as we now understand them. The collections then started have become those now at Kasauli and have been the basis of most of the systematic work done since on anopheles and other mosquitoes of India. Here was started also a special malaria reference library and other activities.

The war had a disastrous effect on this organisation owing to the fact that, for one reason or another, officers of the calibre and status previously available could no longer be spared. Malaria officers were still entertained by some provinces, but they were not of the same stamp as formerly and, with some notable exceptions, work undertaken had lost its original pioneer qualities and drive and was, relatively speaking, unimportant. Most of the malaria work during this period carried out by Indian officers was in the then little known regions of Mesopotamia, Palestine, Egypt, etc.

#### WORK 1920-1927.

This period saw a revival of malaria work, chiefly connected with the renewed activities of the Central Malaria Bureau. There being few facilities for extended survey work, attention was mostly directed to working out certain basic problems. An important enquiry then instituted (and it may be said briefly that practically all such enquiries from this time on have been the result of the activities of the Indian Research Fund Association) was the "Quinine and Malaria Enquiry" under Major Sinton, I.M.S. Largely due to the influence of Major Sinton, this was later associated with a Malaria Treatment Centre at Kasauli, where malaria cases among troops were sent for treatment. Under these conditions were carried out extensive trials of the efficacy of quinine and other drugs, more especially in respect to the all-important matter of prevention of relapses in malaria. The work of this enquiry has been of the greatest value and importance and of the highest quality, all the work being controlled and based on large numbers of cases.

The culicidæ other than anopheles were dealt with by the "Culicidæ Enquiry" under Captain Barraud. It is now difficult to imagine the old state of affairs, for not only is the total number of known species many times greater than was ever supposed existed, but identification has been made available to all workers in India, thus not only assisting malaria workers, but those engaged in researches in many other lines.

The anopheles received intensive attention, and knowledge of Indian anophelines with establishment of some order in the synonymy was brought up to modern requirements. Whenever an opportunity occurred, a survey was carried out. Altogether the policy during these years was one of encouraging and fostering malaria research in whatever way it was found possible to do so.

When in 1925 proposals were put before the Annual Conference of Research Workers at Calcutta for an efficient central malaria organisation, these were received with general approval, and notably by the directors of public health in the provinces, who saw in the establishment of a technically strong central organisation a promise of help in the creation of satisfactory provincial malaria organisations. With this state of affairs, we come to what may be called the present position in regard to malaria research in India.

## THE PRESENT POSITION — THE MALARIA SURVEY OF INDIA.

Pending the taking over by Government as part of the new Central Research Institute, the Malaria Survey of India, as this is now called, has been financed by the Indian Research Fund Association. The formation and recognition of this new body is almost entirely due to the support and sympathy given to the scheme for its creation by Col. J. D. W. Graham, Public Health Commissioner with the Government of India and Secretary to the Indian Research Fund Association.

The Survey is a nucleus scheme intended to work through liaisons, additional Research Fund enquiries and so on. It is the accredited organ for advice, record, co-ordination, advancement of study and stimulation of malaria work generally in India. It consists of the Director, Major J. A. Sinton, V.C., O.B.E., I.M.S., an Assistant Director, Major G. Covell, I.M.S., two research malaria officers, Dr. Bruce-Mayne and Dr. G. Macdonald, and Entomologist, Mr. P. J. Barraud, together with a selected staff, now highly skilled in malaria work, among whom may be mentioned Rai-Sahib Assistant Surgeon Khazan Chand, Sub-Assistant Surgeon J. D. Baily, and Laboratory Assistant Majid, all of whose names will be found in the literature. The headquarters of the Survey is at present a block of buildings at the Central Research Institute, Kasauli, and it has a field experimental station, the Ross Experimental Station for Malaria, at Karnal in the Punjab.

Already this organisation has shown its effectiveness for the position it occupies. Research in all branches of malaria is being actively carried out. The Director is adviser to the Public Services Commission which has the appointment of malaria officers to Government railways and other similar posts. He is adviser to, and in close personal touch with, the anti-malaria work on the new Vizagapatam harbour works and, in general, is in touch with the whole trend of malaria work, including prevention and propaganda work, in India. The important part of the scheme is that officers in it should be able to make malaria their life study and so maintain a permanent spirit of malaria work in this country. The position this organisation is intended to occupy in relation to actual prevention and preventive measures will be taken up later.

## HISTORY OF MALARIA PREVENTION IN INDIA.

### ANTI-MALARIA OPERATIONS.

The following are "operations", arranged more or less in chronological order, that have been carried out in India at various times and places and under different conditions.

*Mian Mir.* — Early operations (1900-1903). These have already been referred to. Operations 1904-1909. Further operations carried out by the military authorities with closing down of all irrigation.

The operations at Mian Mir are summarised in a report by Nathan and others (1910).

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## THE PRESENT POSITION — THE MALARIA SURVEY OF INDIA.

Pending the taking over by Government as part of the new Central Research Institute, the Malaria Survey of India, as this is now called, has been financed by the Indian Research Fund Association. The formation and recognition of this new body is almost entirely due to the support and sympathy given to the scheme for its creation by Col. J. D. W. Graham, Public Health Commissioner with the Government of India and Secretary to the Indian Research Fund Association.

The Survey is a nucleus scheme intended to work through liaisons, additional Research Fund enquiries and so on. It is the accredited organ for advice, record, co-ordination, advancement of study and stimulation of malaria work generally in India. It consists of the Director, Major J. A. Sinton, V.C., O.B.E., I.M.S., an Assistant Director, Major G. Covell, I.M.S., two research malaria officers, Dr. Bruce-Mayne and Dr. G. Macdonald, and Entomologist, Mr. P. J. Barraud, together with a selected staff, now highly skilled in malaria work, among whom may be mentioned Rai-Sahib Assistant Surgeon Khazan Chand, Sub-Assistant Surgeon J. D. Baily, and Laboratory Assistant Majid, all of whose names will be found in the literature. The headquarters of the Survey is at present a block of buildings at the Central Research Institute, Kasauli, and it has a field experimental station, the Ross Experimental Station for Malaria, at Karnal in the Punjab.

Already this organisation has shown its effectiveness for the position it occupies. Research in all branches of malaria is being actively carried out. The Director is adviser to the Public Services Commission which has the appointment of malaria officers to Government railways and other similar posts. He is adviser to, and in close personal touch with, the anti-malaria work on the new Vizagapatam harbour works and, in general, is in touch with the whole trend of malaria work, including prevention and propaganda work, in India. The important part of the scheme is that officers in it should be able to make malaria their life study and so maintain a permanent spirit of malaria work in this country. The position this organisation is intended to occupy in relation to actual prevention and preventive measures will be taken up later.

## HISTORY OF MALARIA PREVENTION IN INDIA.

### ANTI-MALARIA OPERATIONS.

The following are "operations", arranged more or less in chronological order, that have been carried out in India at various times and places and under different conditions.

*Mian Mir.* — Early operations (1900-1903). These have already been referred to. Operations 1904-1909. Further operations carried out by the military authorities with closing down of all irrigation.

The operations at Mian Mir are summarised in a report by Nathan and others (1910).



*Dinajpur.* — Town selected in Bengal for measures. Operations commenced in 1906, continued to 1911. Reported upon by Goil (summary by Bentley) 1910 and by Bentley 1913. Twenty-six coolies employed under two moustiquiers in "minor measures". No recognisable results are recorded.

*Saharanpur, Nagina and Kosi.* — Surveys of the malarious towns Saharanpur and Nagina in the United Provinces by Major J. C. Robertson were completed in 1909-1910, and of two other malarious towns, Kairana and Kosi, by Graham in 1910-1911. As a result of a pecuniary grant by the Government of India towards matured schemes in the United Provinces, the three projects of Saharanpur, Nagina and Kosi were taken up and carried through by the irrigation and other departments concerned. The conditions are reported upon by Graham in 1913 and again very fully by Phillips (1924). The problems involved were mainly those of over-irrigation, water-logging, wet cultivation and incidental breeding-places connected with tanks, etc. In Saharanpur the works were completed in 1918. 80,000 Indian rupees were sanctioned in 1912, and later this sum was considerably increased. Practically all recommendations were carefully completed. In Robertson's initial survey, 2,101 children showed a spleen rate of 78.8 per cent, Phillips in 1923 found only 198 of 2,665 children, or 7.3 per cent with enlarged spleen. This effect appears beyond all question, but there is one possible source of error, viz., that 1909 was the year following the epidemic which affected the Punjab and also portions of the United Provinces. *As is well known in the Punjab, the spleen rate falls steadily following one of these epidemics almost to nil in the course of five or six years.* There is, however, the fact known to us that the spleen rate in the surrounding villages is still high. As regards vital statistics, the evidence, though quoted by Phillips as showing undoubted effects, does not seem very certain, as total mortality figures are not greatly affected. This, however, does not apply in the opposite direction, i.e., want of evidence in the statistics might well not prove that there was no improvement.

Nagina, like Saharanpur, shows a great reduction in the spleen rate as compared with that in 1909 (13 per cent as against 79 per cent) in an examination of 1,038 and 1,957 children respectively. This change is evident in all the wards of the town. Here both total and fever mortality are less in the decade 1913-1922 than in 1899-1912, but there is also a slight reduction in the birth rate.

At Kosi measures do not seem to have been so fully carried out as at the two previously mentioned towns, but the spleen rate in 1923 was about half what it was in 1909 and the statistics are thought to show improvement.

It is highly probable that a great improvement has been made in the malariousness of these towns. In regard to Saharanpur, Major Sinton considers the restriction of irrigation as having been a vital factor, but apart from this the thoroughness with which the sources of anopheles were ascertained and the recommendations carried out gives to these operations a very definite character of municipal improvement, than which nothing appears to be more hostile to malaria.

*Andamans, 1911.* — An example on a small scale of the *A. ludlowi* problem of the countries farther east. Surveyed by Christophers in 1911 and operations carried out on

lines recommended. Reported on in 1922 by Barker and fully re-surveyed by Covell (1926). Results are stated to have been very striking, due to removal of some settlements to healthy sites and filling up of *ludlowi* swamps, where these were of relatively small size and near settlements.

*Ennur*, 1912-1914. — Operations of the nature of filling in borrow-pits and other excavations, notably the numerous pits made in casuarina culture. Reported on in 1920 by T. S. Ross. Ennur, known since 1901 (when visited by the Royal Society's Malaria Commission) as a highly malarious locality and still malarious in 1912, is now greatly improved.

*Madras*, 1912-1916. — Measures taken following appearance of increasingly severe malaria in certain areas. Operations initiated by Hodgson and Russel. Initial grant of 300,000 rupees and annual expenditure of 35,000 (1915). Distribution of quinine by special visiting nurses, dispensaries, etc. Tanks and wells filled or otherwise dealt with. Distribution of fish.

*Delhi*. — Earlier phases. Anti-malaria work at Delhi goes back to 1912 when, with a view to providing data for selection of the site of the new imperial city, the whole area of many square miles was minutely surveyed by Hodgson. On the results of this survey, the suggested northern site was given up and the present southern site adopted. Hodgson's report formed the basis of a good deal of excellent anti-malaria work, and the conditions in many parts of the area are now unrecognisable in contrast to their former condition.

*Lumding*, 1915-1920. — Railway junction in forest area in Assam. Malaria so severe that question of abandonment arose. Operations carried out on recommendations by McCombie Young. Initial grant for pukka drains, etc., 31,022 Indian rupees. Additional operations to include more extended area in 1920. Reported on by McCombie Young in Supplement to Annual Public Health Report, 1921. Considerable improvement. Spleen rate 52 as against 87.

*Pasighat*. — A somewhat similar case in the same area.

*Singanama and Pagara*. — Jungle clearing experiment in two intensely hyper-endemic villages in the Central Provinces. Similar experiments carried out in Bengal about the same time.

*Meenglas*, 1917-1919. — Blackwater fever garden in the Duars. Selected for trial of effect of subsoil drainage operations. Land much cut up by Jhoras (ravines) as is much of this country. Area three-quarters of a mile in diameter, having in view protection of a central experimental area. Reported upon by Stewart (1926). Breeding seems to have been controlled in Jhoras, dealt with, but there is more doubt as to the abolition of malaria. Annual cost of upkeep for this area 800 rupees, initial cost 16,000 rupees. A sporting effort carried out without much help that might have accrued from experience of such methods elsewhere and due to Dr. Bentley's initiative. Though expensive, the type of work now highly developed in Malay States.

*Singaran and Toposi Colliery, Jangipur, Banka Valley (Burdwan).* — Various experiments in different kinds of attempted control. Singaran, 1917-1920. Periodic flushing of river, drainage of rice-fields. Jangipur. Flushing of tank with special drains, etc. Reported upon by Sur (1925). Local authorities taking no action and experiment abandoned. Banka valley, a bonifazione scheme, 1919-1922.

*Sara Bridge.* — Precautionary measures taken during building of the Sara Bridge over the Ganges.

*Sarda Canal Head Works (Banbassa), 1920-1925.* — As above, but more extensively organised. A prevention camp with laboratory and two observers was established on the site of the works. Nalas, pools and stream beds filled in. Drainage. Recognised to have greatly modified the expected amount of malaria.

*Nalbari.* — A Government experimental sugar estate on the grass slopes below the eastern Himalayas. Surveyed and reported upon by Christophers (1921). Mistakes already made, as selection of site should have been first consideration and advice obtained on this. Observed several times by McCombie Young. Malaria affected the experiment, as no staff could be maintained. Project otherwise promising, later abandoned.

*Manhapur (Singbhum).* — Iron-mining area in thick jungly hyper-endemic area. Surveyed by Christophers and survey continued under Wats (1922).

*Bombay, 1908-1929.* — The question of malaria in Bombay first came into prominence in 1908, when a state of epidemic malaria was found developing in the Frere Road and certain areas of the port districts. To Liston belongs the credit of ascertaining that this malaria was essentially due to the breed of anopheles of the species *A. stephensi* (hitherto not suspected to be more than a relatively uncommon species) in wells, even though these might appear to preconceived ideas most unsuitable and unlikely for such breeding. Following these preliminary observations, Bentley in 1909-1910 carried out a most thorough investigation of the malaria conditions throughout the City of Bombay, an almost unique piece of work, in which every aspect of the malaria question was gone into, some 50,000 children examined for enlarged spleen, some 5,000 for parasites, and malaria was mapped out throughout the City. This observer not only furnished a most instructive and important report, but himself initiated actual measures of prevention on lines that have since been followed, viz., strict supervision of all cisterns and wells and the seeing, by municipal legislation, that these are adequately protected (or in the case of wells, filled in or closed). In the succeeding years, this type of sanitation reached a high level of perfection in Bombay, as could be amply demonstrated by accompanying a sanitary inspector on his rounds. Comparison with matters as they formerly were can scarcely be made.

In 1920 an outbreak of malaria on steamers sailing from the Alexander Dock and neighbourhood called attention to a still serious state of affairs in the Frere Road area. The cause of these outbreaks has never been fully explained, but appears most probably to have been the result of breeding of *A. stephensi* in connection with building operations on the Ballard estate. Every open cellar and every cement-laid floor under such circumstances as are present in the monsoon, as well as other related situations, tend to

breed *A. stephensi* freely, thus making building of large modern structures a matter requiring the strictest supervision. All this is now well appreciated in Bombay.

Recently complaints of malariousness has brought up the whole subject of the importance of such a city as Bombay being free from malaria, and at the request of the Bombay authorities a member of the Malaria Survey, Major Covell, has been sent to investigate and report upon the conditions. In this case, again, an almost unique report giving exactly in detail everything required, including a careful survey of the legislation, and based on thorough personal knowledge of all the conditions, has been submitted. In this case, greater rigidity and powers of the inspecting organisation seem called for, but there is a large element of influential local opinion that is hostile to action of this kind ostensibly on religious grounds. Bombay is a unique example of power to control malaria, and it will be unfortunate if further and stricter measures cannot be enforced against the breeding of this one specialised species that has taken to a town habit and appears in the course of time to become more and more firmly established where it has once made a footing.

*Colaba, 1922-1928.* — On certain occasions, reclamation and subsequent operations (building) in Bombay have been associated with outbreaks of malaria. In the case of the Back Bay Reclamation Scheme, advice was asked regarding steps to be taken to prevent the possibility of such result on the present occasion. The action advised was to engage throughout the course of the work a malaria officer who should maintain a constant and close watch over the operations and take such steps as might from time to time be required to control the breeding of anopheles. This work has been very ably done by Dr. Chalma. Colaba, where the chief centre of operations was situated, has not only not suffered any exacerbation of malaria incidence but, owing to the combined action between the reclamation and military authorities, from a place with a high incidence among troops living there, has become almost free from malaria.

These operations, in my opinion, owe their effectiveness to the fact that an adequately trained officer was put in charge with no other duties, fully supported by the engineering staff and kept supplied with what was necessary in the way of funds as the occasion for such expenditure arose.

*Vizagapatam, 1927.* — With the scheme for a new harbour on the east coast of India, engineering and construction work of a large scale have been in progress for some time at and near Vizagapatam. Advice was asked regarding steps it was advisable to take from the beginning, and the Director of Malaria Survey has been in close touch with the malaria position from its start. An engineer on special malaria duty is employed by the Vizagapatam authorities and such funds as are necessary have been forthcoming. Further details of the conditions will be available to the Commission when it visits this spot.

*Delhi (late stage).* — The question of malaria in the new capital came up again in connection with the new underground sewerage, there being some indication that the breeding of culicines at least was in progress and threatening to become a nuisance;

such nuisance being very prone to happen at Delhi, where, at certain times of the year, conditions are very favourable to the breeding of *C. fatigans* and related species. There now exists a sewerage system adapted to avoid mosquito nuisance, *i.e.*, silt traps and certain other common engineering devices unsuitable to the tropics have been got rid of and special horizontal openings arranged. The question of garden irrigation has also arisen and been satisfactorily dealt with.

A relatively mild, but none the less definite, autumnal epidemic of malaria in 1927, however, showed that, in spite of an enormous amount of levelling and filling in that has been undertaken on the city site, malaria was by no means absent. A brief survey was made by me and recommendations made, and in 1928 the whole area was again surveyed with a view to further action. Much has been done at Delhi, but there is a large area involved and the conditions to be combated during the relatively short time of the monsoon (July to September) occur when many people are away. The Survey has undertaken to give the necessary investigation by one of its officers, and is expecting shortly the addition of a malaria engineer to its strength who will, among his first duties, be put on to actual operations in the Delhi area. The conditions at Delhi are of a very mixed kind and description is of little use before the Commission has actually seen these.

*The Punjab.* — Anti-malaria work in the Punjab began especially after the great epidemic of 1908 had attracted attention to the importance of preventive action. Apart from general improvement of conditions in towns, the great problems of the Punjab lie with *water-logging*, other effects of irrigation and the great epidemics which are almost special to this area. The canal systems of the Punjab are amongst the greatest in the world, and the canal authorities are now actively concerned with malaria improvement in connection with all such schemes. Drainage, flood protection, improvement of water-logging have all been actively prosecuted during the last two decades and have constituted anti-malaria work of a high order, involving improvement of health to such towns as Amritsar and different rural tracts. The Commission will have the opportunity of seeing some of this work on its visit to Lahore.

*Coorg, 1927.* — At the request of the Commissioner of Coorg, Col. McCombie Young was deputed to carry out an investigation of malaria in Coorg. Operations at Mercara, the capital, have followed on lines recommended.

*Indian Railways.* — A number of these have appointed malaria officers. In the construction of a new line through the very highly hyper-endemic country north of Vizagapatam, an organised system of selected camping grounds associated with anti-mosquito work was carried out. This is the first time in India that an attempt on these lines has been made to protect labour employed on railway construction under such circumstances. Malaria prevention work is also receiving attention in respect to the protection of employees in malarious areas, etc. This work will be demonstrated to the Commission by Dr. Senior White and Dr. Chalam during the visit to Calcutta. Dr. Senior White was in charge of the operations referred to north of Vizagapatam.

*Sukkur (Sind), 1927.* — With a view to assisting the Bombay authorities in a scheme for anti-malaria work in Sind, and also with the object of studying the conditions

associated with irrigation projects from the beginning, and if possible modifying objectionable features before these arise, an investigation was carried out on malaria in a portion of Sind. The Survey now has a small laboratory on the spot with a view to keeping watch over the various questions connected with canal irrigation malaria.

#### QUININE.

##### *Cinchona Cultivation.*

The existing plantations are at Mungpoo and Munsong near Darjeeling, and at Coonor in the Nilgiri Hills in South India.

The most important recent development has been the investigation of different possible areas in India where cinchona cultivation might be extended (Report by Gage, 1918) and the experimental extension subsequent to this in North Tavoy (Mergui reserve).

##### *Quinine Distribution.*

The notable experiments and developments have been:

1892. — The original so-called "pice packet" system introduced into Bengal. Extended in 1894 to Punjab, Bihar and Orissa and elsewhere in India.

1893. — Prophylactic issue in jails in the Punjab.

1908. — Free issue of quinine during the 1908 epidemic. (Punjab 6,000 lb., United Provinces 7,000 lb.)

1909. — Free distribution in thirty-six most unhealthy thanas in Bengal by nineteen civil hospital assistants.

1911-1916. — Experiments in quinine treatment of school-children in United Provinces by Graham.

1913. — Abolition of "pice packet" system in Bengal and replacement by "treatments". Treatments usually consisted of tablets put up in glass tubes and containing what was estimated to be suitable for treatment of one case. Followed by Bihar and Orissa 1914 (20 4-grain tablets in glass tube), Burma, (5-grain tablets in paper tube) and other provinces as far as replacement of packets by tablets in various forms was concerned.

1912-1916. — Madras. Use of nurses, special dispensaries, etc.

#### MISCELLANEOUS.

##### *Use of Larvivorous Fish.*

1900 (circ.). — Introduction of millions *Pæcilia (Girardinus) pæciloides* De Filippe, into Ceylon. Since stated (Southwell, 1920) to have practically died out.

1909. — Importation of 150 *Girardinus pæciloides* by United Provinces Government (Graham, 1913). A number transferred to Zoological Gardens, Calcutta; considered inferior to the indigenous species of *Haplochilus*, etc. (Rec. Ind. Mus. VII, No. 35).

1909-1913. — Experiment and observation on indigenous larvivorous fish in United Provinces, by Graham, Bengal by Fry; etc.

1912. — Publication account of Indian larvivorous fish, by Sewell and Chaudhuri.

1911. — Introduction of indigenous fish in wells, etc., as part of anti-*stephensi* campaign, by Bentley.

*Larvicide.*

1927. — Paris green used in Bombay anti-malaria operations by Chalam.

*Mechanical Protection.*

Used in many bungalows in planting districts, etc.

Most notable developments are:

1926. — Mosquito-proofing of barracks for British troops at Amritsar, Lahore, (Mian Mir), etc. Results recorded by Munro, incidence from one-third to one-sixth previous figures. Further reported on by Hanafin, 1928.

## THE GENERAL PROBLEM OF MALARIA PREVENTION IN INDIA.

When speaking of a problem of malaria prevention in India, I have in mind the view or policy that should be held by, say, a Government desirous of doing what it can for such a population as that of India, not restricting action to what can be done for the vast rural portion of this population but considering also those sections of it living in towns, carrying on planting, mining or industrial operations, performing the official business of Government and so on. This introduces the various aspects under which malaria is seen, the facts regarding which we must briefly survey.

### HYPER-ENDEMIC MALARIA.

If malaria be mapped out according to the degree of spleen rate in the children and the degree of parasite infestation going along with this, then the most striking feature of this mapping of "endemicity" is *the occurrence of widespread tracts where the spleen rate approaches 100 per cent and where, associated with this, the adult indigenous population is fairly immune*, whilst all immigrants suffer severely from malaria, usually to such an extent that these tracts are only occupied by immigrant races at the expense of a serious amount of sickness and often a liability to blackwater fever.

India as a whole is not this type of country; it is clearly, for example, not so intensely malarious as tropical Africa. Nevertheless, tracts of hyper-endemic malaria are quite extensive. As these are now approximately mapped out, they are shown in a map issued by the Malaria Survey, of which the Commission will be given copies. Such tracts are, in the main, the jungle regions of India. Low hill ranges covered with forest or heavy jungle constitute the majority. Mostly the population of these areas is small, bearing numerically little relation to the vast and dense population of the Indo-gangetic

plain or more cultivable parts of Southern India. The inhabitants also are usually of primitive aboriginal race.

It is somewhat of a paradox that these very parts of India where malaria is most prevalent and intense should be the parts where it is very doubtful whether any action against malaria in respect to the indigenous inhabitants is either necessary or desirable. We do not even know, though it is often assumed, that the death rate in the children is abnormally high. The adult community is largely immune and suffers little. Moreover, short of some very complete degree of improvement, a diminished child immunity might be a serious change to introduce.

The practicable measures in such circumstances would seem to be those having relation to individuals and communities who, as immigrants, visit or live in such areas. For the individuals, such as missionaries, forest officials, police, shop-keepers, etc., the obvious line of prevention lies in personal prophylaxis. A duty to such is to provide them with clear cut and reliable instructions. Such instructions as are apt to be issued are usually inadequate and lack the necessary detail to make them any real use. Further, it is not easy and requires special experience of the actual circumstances to draw up really helpful and correct instructions. Even instructions for the proper use of a mosquito net, it has been found, require a good deal of study (seeing that conditions are not always those pictured by the person drawing up the rules), and actual experience in the field is very necessary. With this proviso, the promulgation of instruction is a most important anti-malaria measure in relation to hyper-endemic areas.

I may mention here that instructions of this kind recently drawn up by Phillips in the United Provinces have been specially printed and distributed by the Forestry Department. Such Government departments, as well as firms, etc., are only too glad to have such assistance, and the attempt to meet such demand by the most carefully and knowledgeably compiled health rules possible is worthy of the greatest attention.

These areas are usually those in which planting, mining and a certain number of engineering works are carried out. Some, such as the Duars, are of great economic importance due to extensive tea planting and other activities which require not only a large European community, but also large labour forces. Such concerns are usually relatively wealthy and can carry out anti-malaria work such as drainage, organised petrolage, etc. Up to the present, however, anti-malaria work under hyper-endemic conditions is usually difficult.

#### ENDEMIC MALARIA.

The great mass of India, with its population of 319 millions, nearly one-fifth of the population of the whole world, equal to the population of Africa and South America combined, and probably twice that of all other population in the tropical and subtropical zone, excluding China, comes under conditions which may be described as a varying but often moderate endemicity. Further, 90 per cent of this population is living under rural conditions. This vast illiterate teeming mass of humanity, living in 687,935 towns and villages, is the real malaria problem of India in its ultimate and complete aspect. The conditions in respect to malaria, it is obvious, must have many aspects.



A considerable number of villages, especially in the north-west, suffer directly or indirectly through irrigation. Engineers are now alive to the evil effects of "escapes", water-logging and other defects, and seek to rectify these as much as possible. Especially, however, with old-standing irrigation, wet cultivation in dry areas, too lavish irrigation and so on, much malaria is apt to accompany irrigation.

The relation of malaria to rice cultivation is of great importance. Wet rice-land under certain circumstances is definitely associated with malaria, but extensive tracts of rice cultivation are often notable for the low spleen rate present. Passing from the jungle and grass terai land with a hyper-endemic spleen rate, it is not uncommon to encounter, as soon as the flatter, wetter rice-land is entered, a quite low spleen rate.

Tracts characterised by decayed rivers in Bengal are, as regards the spleen rate, hyper-endemic, though the conditions are not quite those of the aboriginal hill tracts previously mentioned, adults being much less noticeably immune and having often a high spleen rate. Such areas are among those demanding special action, though what this action should be has been the subject of much discussion.

Bengal has long been a tremendous problem in regard to the question of malaria prevention. Drainage of the low-lying country was formerly considered the only action suitable to the conditions, and a number of large drainage schemes have from time to time been projected or carried out. Latterly, entirely new conceptions as to procedure to be adopted has been put forward by Bentley. Bentley regards decay of rivers due to secular changes in the delta, aided by bunding embankments, etc., as leading to physiographical and other changes suitable to malaria. The question of impaired surface flood drainage by roads, railways, etc., has also been much discussed. Malaria in Bengal, with its population of 47 millions, of which 43 are living under rural conditions and of which immense tracts are suffering severely from malaria, must be one of the most difficult major sanitary problems in the world. In this connection ought to be mentioned the work of the Bengal Anti-Malaria Co-operative Society, which consists of a headquarters and branches in various parts of the country where local village anti-malaria work is carried on. The Commission will be in a position to judge on some of the points raised when in the course of the tour it has the opportunity to see the Bengal conditions and meet Dr. Bentley and others.

Obviously, knowledge regarding what tracts and areas really need to be considered at this stage in malaria prevention work is most essential, and the continued survey of more and more sections of rural India is most important.

In some cases, obvious defects such as water-logging can be remedied. Drainage of some tracts is imperfect and can be improved. Canal ends and major hydraulic defects can be remedied. But, on the whole, the question of village anti-malaria work presents very great difficulties. The number of villages and towns in India has been already stated to be over 600,000. Many of the villages have a considerable population, say from two to five thousand. Roughly speaking, no funds are available other than will just serve the needs of conservancy, etc. Owing to the repeated building of mud and, to a less extent, of cutcha brick dwellings, most villages are surrounded with small

and large excavations, sometimes representing centuries of such procedure. In many parts of India, villages are associated with rocky or sandy nullahs, often fed by a certain amount of seepage, the former especially being a condition expensive and difficult to deal with even over a short distance. Above all, the great vicissitudes in rainfall from one time of the year to another, and even in different years, adds enormously to the difficulty of any set procedure.

These are only what may be called the obvious physical difficulties. Over and above these are those grave difficulties associated with type of population concerned. Here are no capitalised communities of pioneer modern spirits imbued with a progressive modern outlook — familiar with, and ready to utilise, the most recent forms of machinery and scientific invention. On the contrary, in the vast bulk of the population is the conservative spirit of those whose ancestors have always lived as they have — communities whose combined resources are woefully small — so poor that they practically cannot be taxed in the western sense, lacking in public spirit, with a tremendous amount of ignorance and apathy, having no “health conscience” or even any adequate appreciation of what is in the mind of the sanitarian who may attempt to rouse their enthusiasm in such cause. Education in hygiene, not malaria prevention, is the only outlook one can see at present to this vast problem of rural sanitation. Schools, fairs, travelling dispensaries, district health officers, all the elements that go to education and propaganda, malaria exhibits, railway publicity trains, a hundred and one methods, but not yet anti-larval operations. A demonstration under such circumstances of a successful issue to a scheme of village anti-malaria work would be interesting and instructive enough to the malariologist, but it is questionable what the value of operations carried out with all the resources of experts, special staff, an enthusiastic personnel and so on, would be as a demonstration aimed at arousing the enthusiasm of the villagers to sanitise their own village by destroying the breeding-places of anopheles. It is, of course, to some extent a matter of personal opinion what the value of active propaganda in such circumstances might be. It should be, I think, a matter of some interest in this connection for the Commission to see the work in Bengal of the Anti-malaria Co-operative Society. Here the moving spirit is high and unusual, but as strict and logical scientists there is the actual question before us, not only of high ethics and endeavour, but of the actual circumstances and effects achieved. This is a matter for the Commission's own determination, and the grave difficulties in rural anti-malaria work need not be further stressed. Many do not know these conditions and, having experience of other circumstances, they possibly do not judge the question in relation to India as it ought to be judged. On the other hand, those familiar with India almost for a lifetime may be unduly affected by the spirit of the land, but it would not be right as searchers after truth to blur over what is, as a result of matured judgment, believed to be the truth, and this I have not attempted to do even at the risk of being reactionary. Malaria prevention for plantations, industrial concerns, towns and cities and many other circumstances is one thing, a claim that rural malaria in India “is preventable” and therefore why not “prevented” is simply a quibble of ignorance.

### EPIDEMIC MALARIA.

In the drier parts of north-west India, and associated with unusual monsoon rainfall and other conditions, occur, usually at intervals of some years, epidemics of a widespread and "fulminant" character. In the map of malaria distribution already referred to, the area of liability to these epidemics is shown in dark red. The mortality is very high, reaching a rate, during the two months or so at which the epidemic is highest, as much as ten times the normal death rate. Malaria prevention in the Punjab has to deal largely with this type of malaria, the amelioration of which, by the provision of drainage, requires to be more immediately brought to bear by providing sufficient stocks of quinine when and where required. The prediction of such epidemic has been worked at by Christophers and has been brought to a high degree of accuracy by Gill.

### MALARIA IN TOWNS AND CITIES.

The larger cities are usually relatively free from malaria, though in Bombay the prevalence of malaria has caused much anxiety.

The smaller towns, especially in their outskirts, often suffer severely both from endemic and (in the epidemic zone) from epidemic malaria. These towns have few financial resources and their relatively small revenues are quite inadequate to any considerable anti-malaria works. The case of Saharanpur and Nagina show that where suitable and well-planned operations are carried out, they are likely to result in permanent improvement.

A great change is observable in the last few years in the attention accorded to the occurrence of breeding-places of anopheles in towns. Wherever one goes, there is now generally some degree of control of at least the grosser breeding. A good example of this is Delhi where, though there is still a liability to malaria, the conditions relative to breeding-places have become vastly different to what it once was, as I can say from personal experience.

### MALARIA ON TEA ESTATES, MINING AND INDUSTRIAL CONCERNS.

The desire of tea companies, mining and industrial concerns to undertake active steps against malaria on their estates, etc., is clearly increasing year by year. The great need appears to me now to be men trained in malaria work who can be employed by such firms as wish to do this work. At present, after a "survey" and recommendations, nothing very much often follows, largely because it is then left to the manager of such estate to do what he can, whereas the proper course would be to engage a suitable man to reside on the area and see to the carrying out of whatever was possible.

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## REPORT ON THE MALARIA COMMISSION'S TOUR IN INDIA (August 23rd to December 28th, 1929).

### INTRODUCTION.

The Malaria Commission, in carrying out its programme of epidemiological studies begun in 1924, has added to its information in 1929 by making a number of observations and by collecting scientific data of great importance during its journey in India. The Commission's task cannot be called easy, if the extent and the complexity of the malaria problem be considered in a continent of 1,805,332 square miles, inhabited by 318,942,118 inhabitants (1921), belonging to populations differing profoundly in race, language and culture as well as in habits and religion. This problem under different aspects affects specially 90 per cent of the total population—the 286,467,204 inhabitants who live in the 685,665 villages of India. The main occupation of the country people, of whom barely 7.8 per cent can read or write, is agriculture and stock keeping. In British India, 125 million small farmers with their families (73 per cent of the population) get their living out of the soil, while the rest of the rural population is employed on the large plantations, in the mines, in public works, trade, etc. The latter forms of employment lead to perpetual movement in a floating population—an epidemiological factor of capital importance from the point of view of malaria. This cultivated land (alluvial plains or rocky plateaux) owes its fertility to a great system of irrigation whose importance from the point of view of malaria is obvious: the extent of land irrigated is 7.5 per cent of the total in Assam, 8.5 per cent in Burma, 17 per cent in Behar, 3.5 per cent in Bengal, 40.5 per cent in the Punjab, 24 per cent in the Madras Presidency and 73 per cent in Sind.

So far as the statistical figures for 1925 can be taken as a basis, the birth rate was 33.68 per 1,000 in British India against a mortality of 24.7, infant mortality amounting to 174.40 per 1,000 births.

The following took part in the tour in India:

Dr. W. A. P. SCHÜFFNER, Director of the Section of Tropical Hygiene of the Royal Colonial Institute, Amsterdam; Professor at the University of Amsterdam, President of the Group.

Dr. N. H. SWELLENGREBEL, Chief of Laboratory of the Section of Tropical Hygiene of the Royal Colonial Institute, Amsterdam; Professor at the University of Amsterdam.

Surgeon Louis WILLIAMS, Head of the Anti-Malaria Service, United States Public Health Service, Richmond, Virginia, U.S.A.

Dr. S. DE BUEN, Professor of Parasitology, Institute of Health, Madrid.

Major M. PELTIER, Professor of Social Hygiene, School of Sanitary Service for Colonial Troops, Marseilles.

Dr. M. CIUCA, Professor at the Faculty of Medicine in the University of Jassy, Roumania; Secretary of the Malaria Commission.

The Malaria Commission could not have accomplished its work without the help of the health authorities of the Indian Government and of the Indian Provinces and, in particular, of Col. S. R. Christophers, of the "Malaria Survey" of India and its Director, Major Sinton, and Assistant-Director, Major Covell, to all of whom we wish to express our extreme gratitude and our admiration of the perfect manner in which the tour was organised.

The authors of this report, Professor W. A. P. Schüffner, Professor N. H. Swellengrebel and Professor M. Ciuca, have drawn information from the reports and statements of the following persons:

The Public Health Commissioner;

Colonel Christophers (see document C.H./Malaria/135);

Major Sinton and the staff of the "Malaria Survey of India";

The provincial directors of public health;

The malariologists of different provinces;

The head malariologist attached to the Bengal Nagpur Railway (Dr. Senior White).

In the "Bibliography of Malaria in India", the first number of the "Records of the Malaria Survey of India" published by the Indian Research Fund Association (Calcutta, October 1929, 200 pages), Major Sinton has succeeded in listing 2,200 papers (chronologically and according to the books or periodicals) and in adding, not only three indices (subject, author and geographical), but also a list of published and manuscript reports, etc. of the Government of India and different provinces and of some military authorities.

We need not emphasise the absorbing interest of this unique publication to everyone getting into touch with that enthralling subject: Malaria in India.

In the light of Major Sinton's monumental bibliography, any attempt on our part at completeness in our references to literature would be useless and even presumptuous.

In mentioning certain articles and reports, we only want to indicate that they proved in some way helpful in writing this report, but this does not imply that other papers we did not mention were not just as important.

A commentary on the facts noted by the Commission on its tour of four months is contained in eleven Minutes, drafted by the Secretariat with the valuable help of Dr. Peltier. The preliminary report by Professor N. H. Swellengrebel, for whose excellent work the Commission desires once more to express its admiration, constitutes the basis of this report.

The secretarial work has been done by Professor Ciuca with the help of all the members of the Commission.

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In writing the report on our tour in India, we cannot follow the lines adopted in the reports of 1924, 1925 and 1926. This is due to the variety of conditions we encountered, far greater even than in 1924, which make it impossible for the Central Government to institute a general scheme of anti-malarial control as such a scheme must be adopted to the special conditions prevalent in each separate geographical unit.

This explains why the outline of this report cannot be copied from those already existing.

These special schemes can, however, provide a basis for an account of our tour which will not differ too widely from our former reports.

#### A. SOME GENERAL FACTS.

The Indian Empire is divided into provinces and Indian States ruled by semi-independent potentates. Most of these provinces and many of the States are as large or larger than the greater Western-European States. The Indian Empire, consequently, cannot be compared with any of these European States, but must be considered as a whole continent.

Most of the public health work with which we came into touch is directed by the provincial administration and by the health services of geographical units and rural districts, towns, etc., situated within the jurisdiction of the administration.

These units differ, on the one hand, from those of the Revenue Department, and, on the other, from those of the Police Department of the provincial administration. The Revenue Department divides the province (administered by the Governor, with the representative council and ministers) into *divisions*, under the commissioner; the divisions are sub-divided into *districts* under a deputy-commissioner or collector-magistrate, with a district board for rural areas, and city corporations or town committees for each town, acting as self-governing bodies; finally, the districts are divided into "*thasils*" under a "Thasildar". The police administration under the Inspector-General of Police divides the province into *ranges* (under a deputy inspector-general), comprising a certain number of districts (under a district superintendent of police) as in the revenue administration. But these districts are composed of *Thanas* (under a sub-inspector of police), of which a number usually compose a Thasil.

For our purpose, these Thanas are of special importance, as they constitute the units for registration of vital statistics. Their size differs greatly according to the provinces: in the Punjab, for instance, their average size is 200 square miles, with 50,000 inhabitants in 100 villages. In the Thana headquarters, the village watchman or "Chaukidar" recites each week what he remembers of the last week's births and deaths, including the

cause of deaths, according to his own views, and these data are duly recorded by the police officer in the village register which the Chaukidar brings on his visit to the Thana headquarters; as a rule, he is illiterate and therefore does not fill them in himself. These records are the basis of vital statistics in India, but the inadequacy of this system is well known; in many places—Bengal, United Provinces, State of Mysore—it will soon be converted into a more reliable one.

Public health work is the duty of the provincial Government and of the local self-governing rural or urban bodies. The provincial public health service has a definite budget ranging from  $\frac{1}{2}$  to 8 annas<sup>1</sup> per head of the population; this includes the expenditure of a board of public health in providing grants in aid of sanitary work done by the local self-governing bodies. The latter, except for these grants in aid, have to do the best they can with the local taxes they raise. The cities maintain a technical, medical and engineering staff for the execution of their sanitary work, but as a rule the rural boards and those of the smaller towns have to rely on other services, public health and public works, to lend them technically trained officers.

The provincial Public Health Department is under one of the Ministries, which administer the subjects "transferred" to self-government. It is administered by a Director of Public Health who is administratively under the Inspector General of Civil Hospitals, the latter acting as chief administrative officer of the province and controlling all the medical relief. The Director of Public Health is represented in each division or range by an Assistant Director of Public Health and, in a certain number of districts, by a district medical officer of health and by sub-assistant medical officers of health who are partly qualified medical men, assisted by a varying number of sanitary inspectors and vaccinators.

Moreover, the Director of Public Health is assisted by a varying number of assistant directors in charge of special duties, such as direction of institutes, medical propaganda, malaria survey, etc., and of sanitary sections which can be sent wherever they are needed in an emergency. An engineering department and a board of public health may be under his direction or may be independent. In the latter case, sufficiently close co-operation is nevertheless assured.

The Inspector General of Civil Hospitals is represented in each district by a civil surgeon. This officer completely controls all stationary Government medical institutions in his district, like Government and special (*e.g.*, canal, forest, railway) hospitals and dispensaries. He also controls all "local fund" dispensaries in charge of a sub-assistant-surgeon, of the same standing as the Sub-Assistant Medical Officer of Health already referred to, and those town hospitals where the sub-assistant-surgeons in charge are not municipal but Government officials. The number of civil surgeons is so small and their duties so heavy, that even by working twelve hours a day and spending only two hours in each village in their district, they would need two or three years to visit once each village in their district once.

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<sup>1</sup> 1 anna = 1/16th rupee = 1d.

From the above, it will become apparent that a "self-government" Minister in each province is wholly in charge of all public health work and a considerable portion of it is controlled by local self-governing bodies. As the great majority (287 out of 319 millions) of the Indian population is rural, this means that the district boards, with their limited revenues, are responsible for the health of the majority of the people. The financial support they can expect from the central public health administration is limited to the grants in aid from the provincial public health board (these subventions varying between 10 and 12 lakhs of rupees in some provinces), and to any sanitary work that the provincial Government may be willing to undertake for their benefit.

## B. GENERAL ASPECTS OF MALARIA IN INDIA

In the absence of definite statistics of the morbidity and mortality due to malaria, it is impossible to estimate the approximate number of malaria cases; the impression yet remains of the great gravity of the problem so well illustrated in Christophers' and Sinton's chart (1), \*drawn up with the help of the "Malaria Survey". Colonel Christophers' report shows that 90 per cent of the population of India lives in villages. It is this mass of population, only 7 per cent of which can read and write, *that represents, according to these authors, the problem of endemic malaria in all its aspects.*

From the results of these investigations and from our own few observations made on the spot, we have come to the conclusion that the hyper-endemic areas (2) although sparsely inhabited are very often the areas where large plantations and large industrial undertakings are situated and which are therefore often the site of a considerable immigrant population coming from other districts. It is in these hilly districts covered with forest or jungle, with a sparse population, that the immigrants are quickly mown down. Infant mortality in these districts is extremely high.

In other regions (Punjab), fulminant epidemics result periodically in absolute catastrophes if we are to judge by the figures of general morbidity and general mortality, and by the number of cases of malaria admitted to hospital, or even of cases among the town inhabitants living in conditions where they can avoid malaria. The terrible epidemic in 1908 is an example; it produced at Amritsar a greater mortality than the epidemics of plague or cholera. At the same time, the general mortality at Delhi was from 115 to 265 per 1,000.

In all the provinces the mortality from fevers, most of which are attributed to malaria, is higher than from any other disease: 48.4 per cent of all the deaths in Mysore (3) in 1921-1926; in Bengal, malaria cases are said to represent 40.3 per cent of all cases in West Bengal, 32.3 per cent in Central Bengal, 7.5 per cent in East Bengal, and 23.7 per cent in North Bengal.

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\* The references in parentheses are to the Bibliography (see pages 76 and 77).



The percentage of admissions of malaria cases to the hospitals of the United Provinces was 15.06 in 1926. The annual average of deaths from malaria in 1922-1926 was 16.56 per cent of the total of general mortality.

Measured by the spleen rate the incidence of malaria varies greatly in different parts of India. As an instance we may mention the following findings of the "Malaria Survey".

In Bengal, out of 236 villages in which the "Malaria Survey" had ascertained the spleen index, the majority gave percentages of over 25:

Number of villages:	49	39	67	81
Splenic index	0 to 10 %	10 to 25 %	25 to 50 %	50 to 100 %

At Madras, in 242 agglomerations, the following results were obtained:

Number of villages:	77	39	44	82
Splenic index:	0 to 10 %	10 to 25 %	25 to 50 %	50 to 100 %

At Mysore, the splenic index taken in 93 villages was as follows:

Number of villages:	28	15	19	31
Splenic index:	0 to 10 %	10 to 25 %	25 to 50 %	50 to 100 %

In the State of Mysore, the investigations made by Dr. Sweet on 8,143 school-children gives a splenic index with an average per district varying from 3 per cent at Kolar to 64 per cent at Kadur, and with a general average of 22.3 per cent.

This great variation of the incidence as measured by the spleen rate was, moreover, confirmed by the Commission.

## 1. TYPES OF MALARIA.

Speaking generally and discarding details, we may distinguish between urban malaria and rural malaria.

The *urban malaria*, which occurs even in the central wards of large cities and is conveyed solely by *A. stephensi*, will be dealt with in Chapter II, Section A (page 15).

The *rural malaria* (including malaria in the more or less rural outskirts of large cities and in the whole of smaller towns and villages) may be subdivided into malaria in the plains, foot-hills and hills.

The *malaria in the plains* is by no means a regular feature. It often is conspicuous by its absence or scarcity even where rice-fields, water and anopheles (carriers among them) abound (*cf.* Chapter II, Section C). Where malaria exists, *A. culicifacies* is the great carrier. In some areas other species such as *A. philippinensis*, *fuliginosus* and *minimus* var. *varuna* may be important carriers.

Collections of clear, weedy, stagnant or slowly running water are the main breeding-places. The type of malaria is widely different in its incidence, sometimes being distinctly epidemic, sometimes endemic in various degrees.

The *malaria in the foot-hills, i.e.*, the gently sloping plain at the foot of the main hills, deeply intersected by the "nullahs" running to the plains, is almost invariably of the *hyper-endemic type*. The total number of anopheles is often remarkably low, in comparison with the plains.<sup>1</sup> We must assume that anopheles in these areas, breeding in the hill streams with their seepage and swamps, are particularly good carriers. The species found are *A. listoni* and *A. minimus* of the *funestus* group *A. maculatus*, and in Southern India, particularly at the inner slopes of the Western Ghats, *A. jeyporiensis*. Here again, *A. culicifacies* is important, but not to the same degree as the others, according to certain investigators.<sup>(4)</sup>

The *malaria in the hills proper* is very much dependent on the altitude, usually being absent at heights over 5,000 ft., even if carriers are present. Its presence depends, moreover, on the existence of some flat land (valley or plateau) causing the rushing hill streams to slow down, thereby producing seepage and swamps. In favourable conditions, the malaria so produced may be as bad as in the foot-hills. The carriers are practically the same.

In some hill and foot-hill areas, blackwater fever is of common occurrence.

## 2. MEASUREMENT OF MALARIA.

Among the methods used to estimate *the incidence of malaria* the determination of the splenic enlargement in children is extensively carried out. It is a satisfactory method, provided that an intensive quinine treatment and the occurrence of other diseases (Kala-azar) do not interfere, and that the population is a fairly stable one. It can even be used to determine the distribution of malaria over large areas (if it is of a not too variable endemic type), as has been done in Bengal.

The death rate from malaria is gauged from statistics based on figures compiled by the village "Chaukidar" system.

In the Punjab, the epidemic rise and decline of malaria is estimated by the death rate in the malarial season.

Among limited groups of protected persons (personnel of railway stations, for instance) hospital returns and sick rate may prove very helpful, if a comparison can be made with similar figures of non-protected groups.

## 3. SEASONAL INCIDENCE.

In Northern India (Punjab, United Provinces, Bengal), the seasonal incidence of malaria is supposed to be largely dependent on climatic conditions. The dry season,

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<sup>1</sup> This fact was first brought out by Stephens' and Christophers' classical paper on malaria in relation to species of anopheles, the basis of modern "species sanitation". (Rep. of the Royal Soc. Malaria Comm. 1902, 6th Series, pp. 3-10).

both the cool and the hot, greatly reduce the breeding of anopheles, which only become prevalent during the rains (July, August). The malarial season, which begins in August, lasts until November. The less-marked spring peak of malaria, to be found almost everywhere, is largely caused by benign tertian, whereas the autumnal peak owes its existence much more to malignant tertian. The possibility of malaria with long incubation has not yet been taken into consideration. In Southern India, Burma and Assam, where the difference between wet and dry seasons is not so marked, the seasonal incidence does not as a rule differ materially from the one just described, except that the autumnal peak occurs somewhat later.

### C. ANTI-MALARIAL ORGANISATION IN THE PROVINCIAL (OR STATE) PUBLIC HEALTH DEPARTMENT.

In each of the provinces (or Indian States) we visited, the central administration had at its disposal a public health officer who was carrying out malaria survey.

In the *Punjab*, where the Director of Public Health himself had already done so much to elucidate the malaria problem in the province under his care, this Director is, in fact, his own chief malaria officer. But we understand that a malaria officer will be officially appointed.

In the *United Provinces*, one of the assistant directors is in charge of malarial survey, of the training of a staff to carry out anti-malarial work in the province, and of the execution of such work with his staff in selected localities. A similar organisation exists in Bengal, in Burma and in Madras Presidency.

In the *Imperial province of Delhi*, there does not exist a special malaria officer, these functions being discharged by the Malaria Survey of India itself. Anti-malarial work is carried out with unusual vigour, both in *Old and New Delhi* and in the *civil lines* and *notified areas*. In Bombay, there had been a malaria officer, but the post was abolished.

In Mysore, the Government, in collaboration with the Rockefeller Foundation, maintains a department for malaria and hookworm control, which is soon to start practical work.

### D. DISPENSING OF QUININE TO CURE THE SICK.

The Malaria Commission of the League of Nations, without entering into the vexed problem whether quinine treatment should be counted as a preventive measure or not, considers it to be one of the *primary duties of the Government* to arrange for adequate medical assistance to the greatest possible number of malaria patients. We wish to deal with this point separately.

Speaking generally, a malaria patient belonging to a rural area finds several ways open to obtain quinine:

1. *At the dispensaries* (municipal or district board or travelling) <sup>(5)</sup>, maintained either by the medical department or by local funds. These dispensaries are far apart, each one providing for an area with an average radius of ten miles.
2. At the *Thana* (police) headquarters of every registration area.
3. At the headquarters of the *district boards*.
4. At post offices.
5. *At the village headman's*, the schoolmaster's, the village priest's or any other village notable's house. This brings the quinine much nearer home, provided the stockholder is inclined to give the applicant the drug free of charge. We understand that therein lies the difficulty.
6. By means of vaccinators, sanitary inspectors, health officers and other officials of the *Health Department*, when they visit a village on their regular rounds, which may be once a month or less.

In the absence of any further organisation, except as mentioned below, this may be pronounced insufficient to provide for the treatment of the patients suffering from malaria in any given district; but in many instances measures have been taken to render this organisation more efficient.

In the Punjab, the Director of Public Health, <sup>(6)</sup> acting on the assumption that a severe outbreak of malaria was to be expected this year, sent out circular letters at the end of July directing that stocks of quinine should be replenished in the districts threatened.

In the United Provinces, there are thirty-six villages with so-called "school dispensaries" under the schoolmaster—where every child who is ill gets treatment of some kind and where the schoolmaster, through the children, gets in touch with the families.

In Bengal, the sale of quinine in the post offices is supposed greatly to assist the dispensing of the drug among the population. <sup>(7)</sup>

The quinine distribution by local popular effort and that among the employees and workers of industrial or agricultural bodies will be considered separately.

The form of quinine used for distribution in rural areas is the tabloid containing 5 grains of quinine sulphate or an equivalent dose of cinchona febrifuge. This last drug, costing 9 rupees per lb. against 18 rupees for quinine sulphate, is extensively used for distribution.

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## II. THE FOUR CHIEF LOCAL MALARIA PROBLEMS.

We have encountered four main local malaria problems, which will have to be dealt with separately, as they require widely different control measures.

They are:

- A. The urban malaria problem;
- B. The Punjab problem;
- C. The Bengal delta problem;
- D. The hill malaria problem.

The first one is definitely related to one species of anopheles, *A. stephensi*; the other three are not necessarily dependent on one species only.

### A. THE URBAN MALARIA PROBLEM.

This, in fact, is not a problem at all, as it has been cleared up by the work of Bentley<sup>(8)</sup> and Covell<sup>(9)</sup> in Bombay and confirmed by findings in various other cities and towns (e.g., Lucknow, Delhi, Calcutta, Vizagapatam, Bangalore).

The main facts are these: *A. stephensi* breeds in wells, even in deep wells, inside houses. It also breeds in closed (but not hermetically closed) cisterns on the housetops. It may breed in other more natural breeding-places—in fact, it is sometimes found to do so in rural areas, more frequently than its counterpart in the Near East, *A. bifurcatus*. It may also breed in other artificial breeding-places, as in shallow water left in buildings under construction to allow the concrete to settle, also in earthenware vessels, near wells, etc. But for all practical purposes we may consider *A. stephensi* in urban areas to be a well and cistern-breeder only. (See Figs. 1 and 2.)<sup>1</sup>

The malaria it causes is of a curious type and not so easily detected by ordinary routine examination (i.e., by taking the spleen rates of school-children). It occurs in patches (sporadically), is extremely local and is probably—although this is a point which still awaits further investigation—even more closely localised in particular houses than the malaria caused by such typically domestic mosquitoes as *A. maculipennis* in many parts of Europe and *A. ludlowi* in Netherlands India, for *A. stephensi* is domestic, not only as an adult but also in the larval stage, and that the others are not.

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<sup>1</sup> The photographs so referred to throughout the text are reproduced at the end of this document.

*A. stephensi* does not leave the house at all, because it need not do so to deposit its eggs. This explains why *stephensi* malaria occurs in small patches. Only now and again, for reasons not yet understood, there is a more general outbreak showing unsuspected parts of a city to be highly malarious, as was the case this year in Lucknow. Another characteristic of *stephensi* malaria is its occurrence in the central wards of cities, whereas ordinary malaria, as a rule, only affects the outskirts.

Dealing with this problem is intrinsically simple and—as it affects densely populated areas—comparatively cheap. That Bentley's fundamental discovery has yielded so little practical results in Bombay is partly due to religious opposition and partly to the lack of co-operation between the four main governing bodies—the city corporation, the Port Trust, the railways and the provincial Government. Similar difficulties are met with in other cities, even in Delhi, where the campaign against *A. stephensi* has been carried out more thoroughly than anywhere else. We must hope the example in other politically less advanced and more simply governed cities, like Bangalore, where the objections raised in Bombay and elsewhere seem to carry less weight, will eventually induce the larger cities to take the necessary precautions which should have been attended to years ago.

## B. THE PUNJAB PROBLEM. (10)

The geographical aspect of this problem is as follows:

A large flat plain with very little gradient; through it run five great rivers from the north-east to the south-west; the soil is fertile; the main crops are dry crops: wheat, millet, etc. Except for the areas near the river, the western part of the Punjab was a desert till it was irrigated by huge canal systems. In the same way, the higher portions of the land, between the rivers (doabs) now profit by canal irrigation, whereas formerly they were dependent on the monsoon or on wells from which the water was drawn by Persian wheels (modes of irrigation which are still common in many parts of the country). (See Figs. 3 and 4.)

During heavy monsoons the land is often flooded, and these floods invariably cause much damage to the crops and are considered as an unmitigated calamity.

The extension of the irrigation to the western parts of the country has resulted in a continuous rise of the level of the subsoil water in the areas alongside the canals. These areas, where the subsoil water remains at the level of the soil long after the monsoon is over, are particularly liable to long continued and destructive flooding. Moreover, the rising subsoil water in these "water-logged areas" carries to the surface mineral matter (sodium chloride, lime compounds, etc.), which is precipitated on the surface, owing to the strong evaporation. During the dry season it forms a white deposit covering the soil. Such land is called "Kallar". In addition to this mineral deposit which forms in "Kallar" soil, rocky formations of a curious coral-like shape (Kankar) form a few feet under the surface. Owing to the constantly high water-level, the extreme danger of

flooding, the formation of "Kallar" and "Kankar", many of the water-logged areas have been thrown out of cultivation completely. Until recently, the canal department, which takes the water where it is wanted, did not remove excess water. The Irrigation Department has now turned its attention to the problem of drainage of water-logged areas through irrigation canals traversing them. <sup>(11)</sup>

Flooding—even the ordinary flooding during average monsoons—and water-logging form numerous pools, which are the more permanent the deeper they are—*e.g.*, borrow-pits, natural depressions, etc. These and the smaller distributing channels, pools in river beds when the monsoon is over, disused wells (after floods many wells are damaged and thrown out of use), and also the few rice-fields, etc., form the breeding-places for anopheles. They may all breed *A. culicifacies*, which in the Punjab is in all probability the *chief carrier*, but there is no doubt that this species prefers the clear weedy water to the silty water of the non-permanent wide but shallow pools left shortly after the floods. Consequently, in water-logged areas, with numerous permanent collections of water, there are more breeding facilities for *A. culicifacies* than in the parts where the subsoil water-level soon goes down after the monsoon is over. The old dictum of Pringle, that one has only to look in the wells to know the state of health of the locality, holds good for the Punjab.

It would, however, be a great mistake to conclude that the high water-level simply means more anopheles and consequently more malaria. If that were the case, a great portion of the Punjab should be a country where the population is constantly suffering from malaria, and this is by no means the case. We were shown villages near prolific breeding-places of *A. culicifacies*, where spleen rate (children) was nil and others where it was only 10 per cent. The Punjabi, as a whole, are a strong and healthy people—the best fighting men in India. In fact, the malaria problem could hardly be called a serious one, were it not for the occasional outbreaks of terrible and widespread epidemics sweeping over the whole province, leaving no place untouched and affecting even those localities which are as a rule free from the disease. At such times, the mortality rises to unprecedented heights during the malarial season.<sup>1</sup> This is what may be expected among a population so little affected by malaria in the usual course of events, and renders the epidemics veritable catastrophes, impressing the public mind much more than the insidious, non-epidemic malaria in other parts of India.

It is probable that these epidemics take their origin in various localities where malaria is always highly prevalent. We were shown a striking example of this kind in the village of Indri near Karnal, where the spleen rate was over 80 per cent in September, whereas in other villages the spleen rate remained well under 20 per cent.

But whether these "permanent foci" are due to a greater accumulation of *A. culicifacies*, and whether the widespread epidemics can be explained by a sudden and unusual multiplication of the mosquitoes belonging to this species, is a matter which requires much more investigation.

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<sup>1</sup> The extent of the epidemic is measured by the relation existing between the mortality in April and October. If the latter is more than 2.5 times the former, epidemic conditions begin.

According to Colonel Gill and his co-workers, *A. culicifacies*, far from being the principal factor, plays only a subordinate part in causing the epidemics. The evidence he collected appears to him sufficient to maintain that the density and distribution of anophelism are constant, that they do not increase or change appreciably in times of epidemic and that the occurrence of epidemics cannot be explained by a change in the anopheline incidence. The flooding, the increase in water-logging, which no doubt might cause an increase in anopheles breeding and development, act, according to him, as adverse economic factors affecting the physical state of the population. The anopheles factor enters into Colonel Gill's scheme only in so far as excessive rains causing flooding and water-logging increase the *atmospheric humidity*, tending to prolong the life of each individual anopheles, thus rendering it better able to transmit malaria. Apart from the economic factor and the humidity, the advent of an epidemic is, according to Colonel Gill, determined by the degree of diminution of *immunity* of the population, *i.e.*, the time elapsed since the last epidemic and the increase in non-immune human material, *i.e.*, the number of children born since the last epidemic. Excessive rainfall, causing adverse economic conditions by flooding and water-logging, especially if these conditions were already bad owing to a number of dry years, a high birth rate and a long spell of healthy years, predicts the advent of an epidemic outbreak of malaria. In the absence of these epidemics, malaria in the Punjab is not a public health problem of primary all-absorbing importance. It does not sap the people's strength, but it suddenly strikes and kills. The duty of the public health officer is therefore to take precautions against this sudden onslaught. That is what Colonel Gill is doing, when he tries to find the means which will allow him to forecast the epidemic, and when acting on this forecast he takes, with the medical department, measures to assure prompt treatment of all the victims of the impending catastrophe and to improve, by supplying food, clothing, housing and other means, the physical condition of the population. The more permanent work—guarding against water-logging—is, or will be, the task of the canal department.

Whether Colonel Gill's forecast fails or proves correct in a particular instance does not detract in the least from the soundness of his point of view, and does not relieve him from the duty of continuing to make his forecasts and to act upon them, even if this should involve a number of measures which afterwards prove superfluous. All he does is necessary and should be done in any event, and, for the moment, he can hardly be expected to do more than try to render his relief work more efficient.

It is assumed that the epidemics come and go without any notable change in the anopheles factor and the conclusion is reached that the human factor (economic and demographic) is the principal determining factor. This conclusion may be correct, but at present there are not sufficient data to show that the number of malarial vectors is less: (a) in non-epidemic years; (b) outside the permanently malarious foci during non-epidemic years. But if this should prove to be otherwise, if the anopheline factor should prove to be a variable one, then the question whether it can be influenced becomes much more important, even if we are convinced that anti-larval work during epidemics is impossible because of the magnitude of the task. There always remains the alternative of limiting the work to endemic foci. Where are these foci, and what would it actually cost to reduce malaria



in them by anti-larval measures ? We do not yet know but we understand that experiments of this kind will be carried out in the Punjab.

### C. THE BENGAL DELTA PROBLEM. (12)

This apparently is just the reverse of the Punjab problem. In the Punjab, land bearing dry crops is thrown out of cultivation by an excess of water, combined with the Kallar and Kankar phenomenon intimately connected with the excessive dryness in some seasons, whereas in some parts of Lower Bengal land yields poor crops through lack of sufficient water for the cultivation which is almost exclusively wet.

The healthy land in Lower Bengal, as we saw it on the eastern banks of the Padma (e.g., at Tarpassa) looks more flooded than the worst water-logged areas in the Punjab. Even after the rains are over at the end of October, the land seems a huge swamp, but all covered with rice, cane and jute. The rice has particularly long stalks and has to be cut from a boat, only very heavy floods submerging it. The ordinary floods to which all this land is continually subject during the rains and long afterwards do no harm at all because all the crops are wet crops and are accustomed to grow, not in well-dyked fields where the amount of water is nicely regulated, but in actual swamps exposed to the wear and tear of rushing water ("bheel" rice-fields). On the contrary, these floods improve the soil, because the silt suspended in the water during the rains from the end of September onwards gradually settles and acts as an indispensable fertiliser.

Perhaps it is not so much the lack of water as the lack of this fertiliser which renders the fields in the western portion of Lower Bengal—the malarious portion—so much less fertile. For there is, to the eye of the uninitiated at any rate, water enough to cover all the rice, cane and jute fields. But it does not get there by floods; it is supplied to the fields out of the numerous collections of water: "dead rivers" (stagnant watercourses, which, on the map, look like one of the many arms of the Ganges and the Brahmaputra delta), or tanks, often protected by bunds and specially used to supply drinking-water.

All this water is stagnant even during the rains, owing to the formation of alluvial areas by years of sedimentation which have transformed the water-courses into "dead rivers"; these elevated areas are sometimes found alongside of other regions which are flooded during the rains by the silty water of running rivers. The surface waters of the higher ground, however, untouched by the floods, become stagnant and clear by a process of sedimentation.

Consequently, this water allows of a luxuriant growth of submerged as well as floating aquatic vegetation, but it no longer fertilises the soil. (See Figs. 5 to 7.)

Why are the low-lying, flooded areas healthy and the dry and elevated ones malarious ?

The economic factors in the former are no doubt more favourable. This is even more important than is at first apparent, considering that the agricultural conditions a century or less ago were as favourable in the (at present) high land as in the low-lying

area. At that time, the taxes permanently settled were based on the value of the land, and nowadays the taxes are as high as those paid when the net profit was much higher.

Still, the economic factor does not furnish the whole answer to the above question.

As in the Punjab, the anopheline conditions are the same in malarious and non-malarious areas. The principal vectors, as has been proved by the careful work of Sur in Krishnagar (13) and of Iyengar (14) in Calcutta, are representatives of the *fuliginosus* group, principally *A. philippinensis*, also *A. fuliginosus*. Moreover, a variety of the *funestus* group *A. minimus* var. *varuna* is strongly suspected of being a carrier. *They occur in both areas, and a comparison of villages not far apart, one in the malarious, the other in the non-malarious area, has made it clear that they occur in approximately the same numbers.* So far everything is like the Punjab, but still there is an important difference. The investigators in Bengal have gone one step further by asking what is the anopheles season in both areas. They have found that the *maximal anopheles density* in the malarious area coincides with the malarial season, whereas in the non-malarious areas it occurs in November, when the malarial season in the malarious area is over except for the relapses.

The causes of this retarded development in the non-malarious areas, where breeding does not begin till the end of September, are twofold. The extensive surface of water shows much less "edge" than the same amount of water split up into numberless small pools. The edges afford the best opportunity for breeding, unless there is much aquatic vegetation, and this vegetation is absent in the water which is heavily laden with silt.<sup>1</sup> Presence of silt and comparatively short edges—the former factor being by far the more important—prevent breeding (except occasionally that of *A. subpictus*), during the rainy season in the non-malarious areas. Clear water and plenty of edges in the dead rivers of the higher areas not subject to flooding allow of breeding during the rainy season, so that adult malarial vectors infest these areas exactly at the time propitious for the transmission of malaria.

But why should this phenomenon of retarded development cause the absence of malaria? Why is there no malarial season in November and December—as, for example, in Mysore—in the flooded area? We have received no satisfactory answer to this question. That the temperature in November is too low for transmission is an argument we can hardly accept, considering that the sporozoite rate of *A. philippinensis* in November 1928 was still 1.4 per cent (Krishnagar). Perhaps the human factor plays a part even here by accelerating the rate of cure at this time of the year, or perhaps the habits of anopheles differ in some way in the non-malarious areas. At any rate, there exists here a gap in our knowledge, which would make it difficult for us to accept this explanation of the "anophelism without malaria" in the flooded districts of Lower Bengal, were not these findings wholly confirmed by Ramsay's investigations in the non-malarious Surma valley (Assam) and the adjoining malarious tea-gardens in the hills. (15)

Here, again, we find, at a high level, comparatively dry land with nothing but drainage ditches and hill streams, a few tanks and swamps, and a low-lying rice-growing plain

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<sup>1</sup> We do not know whether the vegetation is absent because of the silt.

completely flooded during the rains. In the dry season, when the water is clear, *A. minimus* breeds in the plains in great numbers, but not during the rainy season when the water is silty. In the hills, this species breeds during the rainy season in the clear stagnant portions of hill streams, if they are not too heavily shaded, and in impounded tanks. After the rains, many of these breeding-places disappear, whereas they become abundant in the plains, where the water becomes clear and in permanent water collections. Consequently, at that time *A. minimus* breeds more abundantly in the non-malarious plain than in the malarious (hilly) areas, and it is no wonder that some investigators—unaware of this change of breeding-place from the non-permanent water in the hills during the rains (“summer-resorts”)<sup>1</sup> to the permanent water in the plains after the rains (“winter resorts”),<sup>1</sup>—pronounced the latter to be highly malarious because of the many *A. minimus* they found there, although the actual spleen rate is very low.

Why *A. minimus* does not transmit malaria when breeding in its winter resorts in the plains of Southern Assam is just as incomprehensible as why *A. philippinensis* and *A. minimus* var. *varuna* do not transmit malaria in the flooded areas of Lower Bengal. But the fact remains that the plains are healthy and that highly malarious tea-gardens have been rendered healthy by merely doing away with the “summer resorts”. The independent evidence of Lower Bengal and Southern Assam, which is so strikingly confirmatory, although collected under widely different conditions and relating to different species, leaves little room for doubt of Bentley’s statement that the absence of malaria in Eastern Bengal is due to the circulation of silt-laden river water flooding the fields which grow wet crops.

If that opinion be accepted, the results are far-reaching, for Bentley’s theory goes farther. He holds that the conditions in the western portion of Lower Bengal a century ago were similar to present conditions in the eastern portion. At that time, the land on the west was just as fertile as it still is in the east. It was just as freely flooded during the rains, since the “dead rivers”, which we have described as ordinary delta branches of the Ganges-Brahmaputra, were in fact irrigation canals and formed part of an ingenious and highly effective system of flood-irrigation.

But this system has been destroyed:

1. Because the “Khalkundi” and “Sayer” taxes were abolished at the time when the permanent settlement of taxes was made. The profit from these taxes was used to maintain the canals for irrigation and navigation purposes and the system was thus deprived of its financial basis.

2. Because a third tax was retained, the “Poolbundi”, for the maintenance of bridges and embankments, which are so dangerous for canals if they are not constantly dredged.

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<sup>1</sup> “Winter resorts,” i.e. the breeding-places of anopheles in the permanent collections of water during the autumn, and “summer resorts”, i.e., the breeding-places during the rains, are expressions borrowed from Ramsay.

3. Because roads, railways and embankments, which blocked still further the canals and kept the silt-laden fertilising flood-water off the arable land, were constructed.

4. The permanent settlement prevented the deterioration of the soil being noticed except by the actual tiller of the soil (a person without political influence who suffered most therefrom).

This deterioration has had the triple effect of impoverishing the population, lowering its intellectual standard by driving the better classes to the cities, converting the breeding-places from "winter resorts" into summer resorts (to use Ramsay's expression) and thereby converting the hitherto potential malaria vectors into actual ones.

Bentley's scheme to eradicate malaria in Lower Bengal is the logical outcome of this opinion. No special anti-larval measures are needed; merely the re-establishment of the old system of irrigation by dredging the canals and improving embankments, roads, railways and bridges, so that they no longer obstruct the free flow of water. It is an economical and agricultural measure, which will not prevent anopheles breeding, but which will render them harmless.

The only serious danger remaining after this has been done will be the bunded tanks. In Lower Bengal, these bunds<sup>1</sup> are pierced by sluices, which are at present useless because there is no silt-laden water to enter through them. But in the Surma valley, inhabited by Bengalis, where such tanks also exist and where there are floods, tanks are still dangerous; in fact, they are the only source of malaria in the plains. The water is used for drinking purposes and is intentionally kept clear. It is evident, therefore, that the tanks will require special supervision, even after Bentley's scheme has been carried out.

So long as this has not been done, the public health authorities have to limit their work to *the treatment of malaria patients, by facilitating as much as possible the distribution of quinine*. Quinine is also sold in the post offices, which, we understand, are widely used by the population for this purpose. There are also the sick clubs, maintained by the population itself, with which we will deal in its proper place.

#### D. THE "TERAI AND HILL" MALARIA PROBLEM.

This problem is not quite on a level with the three preceding ones. In the latter, the epidemiological problems have given rise to a general system or at least a definite plan of malaria control. That is not the case with the malaria now under consideration. Moreover, the malaria of the cities in the Punjab and in Bengal is all more or less man-made as far as the anopheles factor is concerned, whereas in the hills it is, as a rule, natural.

When approaching the hills from the plains, which may be low-lying alluvial plains or plateaux, we come across a gently sloping area, where the streams, which have run down

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<sup>1</sup> Bund = local name for embankment or levee.

the hills at a great rate, slow down gradually. Following a meandering course, the streams cut more or less deep ravines with wide river beds in a usually light soil, forming frequent swamps, until the plains are reached, where the water is absorbed in the cultivated fields. The area here described is the foot of the hills. In the United Provinces, in Rohilkand, it bears the name of Terai; the same name occurs again in North-West Bengal and, in the North-East Bengal, a fundamentally similar area, to the east of the Teesta, has received the name of Duars.

The hills proper may differ greatly from the foot-hills. The streams may be rushing torrents in the rains, running quite dry when the rains are over, without any seepage, swamps or pockets in their course. But very often all these features are present, especially in valleys and on plateaux, and in that case the physical conditions in the hills proper do not differ much from those in the foot-hills as far as breeding of anopheles is concerned.

The Anopheline fauna of these areas differ from that in the plains as it includes the hill breeders: the *funestus* group, *A. maculatus*, *A. maculipalpis*, *A. jeyporiensis*, etc. They have this in common that they require clear water—which may be perfectly stagnant—without silt and not too densely shaded. *A. listoni*, *A. minimus* and *A. maculatus* are the principal malaria vectors. *A. culicifacies* is present, but usually breeds in the beds of larger streams<sup>1</sup> only. It seems to be a less important carrier than in the plains. The anophelines of the *fuliginosus* groups are likewise present, but have never been found carrying malaria in the hills.

Provided they breed in the right season (from July onwards), these anophelines must be very potent carriers, for although they are usually only present in small numbers<sup>2</sup> they maintain a high spleen rate among the population, stamping these districts as "hyper-endemic", i.e., with a spleen rate of over 50 per cent. Moreover, in many instances, malaria is associated with blackwater fever among the immigrants.

The fact that the foot-hills and hills are so often associated with immigration is due to two causes. First, these areas are often sparsely populated with more or less primitive aboriginal tribes and therefore invite immigration from the crowded plains, the more so as the soil in the foot-hills is often very fertile (e.g., the Terai in Rohilkand).<sup>(16)</sup> Secondly, they are often very suitable for growing tea (or coffee), though labour has to be imported from elsewhere. (See Figs. 8 to 13.)

*Malaria in these areas appears in its worst form, if this immigration is not accompanied by adequate medical and economic measures, i.e., when the immigrants, although receiving grants of land, are made to shift for themselves.* This condition may be studied in the Rohilkand Terai. The soil requires a certain amount of care, good crops cannot be had without adequate irrigation, and the country, unless sufficiently populated, is so wild that immense, often ruinous, destruction by wild animals is unavoidable. When this is

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<sup>1</sup> A rule not without exceptions.

<sup>2</sup> Here an unsolved problem is presented. (Cf. Stephens & Christophers, *loc. cit.*, p. 33.) If present in small numbers and still causing a high malarial incidence, one might expect an exceptionally high infection rate among them. But this rate is not so high, at least, not invariably so. *A. listoni* and *A. minimus* seem to be less attracted by cattle than *A. culicifacies* (Dr. Senior White).

added to malaria raising the spleen rate almost everywhere over 90 per cent, it is not difficult to understand that an infant mortality of over 500 per thousand (69 births and 38 deaths under one year), and a general mortality of almost a hundred, against a birth rate of half this figure, quickly wipes out one village after another, so that the average lifetime of each village hardly exceeds ten years. Where the Government provides irrigation, these unsatisfactory conditions are concealed by a more plentiful immigration.

It is evident that under such conditions the only means of improvement are a well-organised *medical supervision* of the immigrant settlements combined with the necessary agricultural training of the immigrants, who as a rule do not belong to the best population of the plains, but are more or less desperadoes who take their chance in venturing into such notoriously unhealthy country.

If this policy of medical supervision cannot be followed, the alternative is to stop immigration altogether, unfortunately a very unsatisfactory procedure, to which, nevertheless, we understand the Government has resorted at least as far as the irrigated areas are concerned.

Severe mortality from malaria is not the general rule. Even in such notoriously unhealthy hill country like the Nagavalli valley, in the north of the Madras Presidency, the scene of the construction of the Raipur—Vizianagram railway, Telugus have for generations immigrated from the plains where there is little malaria; and though in the hills they suffer from malaria and have not yet by any means become immunised (as shown by a high spleen rate among adults) they nevertheless succeed in holding their own against, and even gradually driving back, the aboriginal population.

Conditions greatly improve if the immigrant population is well-housed, well-fed, well-cared for medically and sanitarily, even without any special anti-malarial precautions. With the latter, many a "death-trap" has been changed into a health resort. That a country as unhealthy as the Bengal Terai, where in the sixties Lady Canning contracted a fatal infection by spending one night there, is now the scene of flourishing agricultural industries, shows that it can be settled by Europeans and Indians without paying too heavily in health and life and, as in Southern Assam, even with impunity if thorough anti-malaria precautions are taken.

The aboriginal population of these areas is supposed to stand the climate with impunity through being accustomed to it from childhood. In the Rohilkund Terai, inhabited by the native mongoloid tribes of the Tarus and Buxas, some hold that there is a "racial immunity", whereas in other native tribes the acquired immunity is said to be shown by the low or nil spleen rate among adults. Unfortunately, the short time allowed for our tour made it impossible to examine either of these phenomena. Although we often had the opportunity to examine such aboriginal tribes, they evidently were already somewhat affected by the influence of civilisation.<sup>1</sup> At any rate, their children were as much

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<sup>1</sup> This, at least, was considered the cause of our failure. We must confess that we fail to see how the process of immunisation or the acquisition of racial immunity can be affected by contact with "civilisation" unless the aborigines, immunised against their own strains of malarial parasites, fell a victim to those introduced by the immigrants.

affected by malaria, and the case fatality was as great as among the immigrants and, although the splenic enlargement of the adults was less, their spleen rate was still so high as to preclude the idea of even an acquired immunity. Nevertheless, they often looked better than the immigrants, but that might be the outcome of better economic conditions.

## E. SUMMARY OF CHAPTER II.

Of the four great problems in the cities, in the Punjab, in Western Lower Bengal and in the foot-hills and hills, three have led or will eventually lead to a definite and logical system of malaria control. In the rural Punjab, this system is confined at present to medical and social relief work and to efforts to improve conditions with respect to water-logging and flooding. In the cities, the campaign is solely directed against *A. stephensi*, although in some cases it will eventually lead to a sanitary achievement of primary importance, namely, the provision of a continuous pipe water supply.<sup>1</sup> In Bengal it is similar to that in the Punjab, with, however, the following great differences: (1) that the emergency medical and social relief work, owing to the endemic condition of malaria, is of much less avail; (2) that the agricultural improvement is expected to have an immediate effect on the anopheline fauna and to amount practically to anti-larval work.<sup>2</sup>

As a rule operations directed against foot-hill and hill malaria have not been carried out except in the special cases mentioned in Section C of the next chapter.

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<sup>1</sup> Even such a water-supply may prove inadequate to cope with the *A. stephensi* problem unless it is sufficient to allow of the supply being continuous. If it is intermittent only, it will have to be supplemented, as in Bombay, by cisterns which are almost worse than wells.

<sup>2</sup> Fawcus quotation.

### III. EXAMPLES OF MALARIA CONTROL.

#### A. TRAINING OF STAFF.

We begin with this point, as it is recognised in India to be the most important of all.

Training of medical men is carried out in the Ross Institute for Field Research on Malaria in Karnal (Punjab). The teaching staff is composed of the director, assistant director and five members of the "Malaria Survey" in India (headquarters Kasauli). The programme, <sup>(17)</sup> comprising lectures on the whole field of malariology, laboratory work in the parasitology and entomology of malaria and fieldwork to acquire the necessary practical knowledge to carry out a malaria survey, takes six weeks and is attended by a varying number of students sent to the field station by the provincial health departments and other public and private bodies. (See Figs. 14 to 16.)

During our tour, we often met former pupils of this class and came to the conclusion that the "Malaria Survey" contributes much more to the fight against malaria in India than meets the eye of the casual observer.

We understand that the practical part of the teaching in the Karnal field station is to be extended by carrying out, in some neighbouring villages, control work on various lines, including anti-larval work, with the necessary observations in uncontrolled villages to ensure clear and certain results. There is no doubt that the students will greatly profit by this addition to their class work.

Similar teaching, although necessarily on a smaller scale and with a less perfectly equipped staff, is carried out in the provincial hygienic institutes in Lucknow and Rangoon. These institutes are, however, of special importance for the training of the auxiliary staff, *i.e.*, of sanitary inspectors who are trained in malaria control work, including the technique of anti-larval control in all its phases.

#### B. METHODS OF ANTI-MALARIA CONTROL.

Before Ross's great discovery, the campaign against malaria in India was in the clinico-therapeutic stage as in all malaria countries. The statement made by Colonel Christophers at Karnal made us realise the great part taken by India in the botanical studies which resulted in the plantations of cinchona and the manufacture of quinine. The studies on cinchona febrifuge date from this period before 1887.



The spread of malaria in India made it impossible to limit the problem to the individual treatment of the sick, and Dempster in 1845 brought out the importance of the study of epidemiological factors in the spread of malaria, the determination of the splenic index being the method of measuring the incidence of malaria.

Ross's discovery and the work of the Malaria Commission of the Royal Society led to the study of the biology and habits of the many species of anopheles. Work of great scientific interest due to the Indian School of Malaria brings out the incontestable importance of the investigations required for an anti-malaria campaign—investigations which are centred in the "Malaria Survey" of India. It is the great spread of malaria and the number of species of mosquitoes transmitting it, together with the economic and social conditions of the different populations, that have influenced the choice of methods for the campaign and the programme of instruction given in the Malaria School at Karnal and in the provincial health institutes, which attach great importance to entomological study. The local epidemiological conditions and the high cost of the work have strictly limited the application of the measures which are reserved in the main for urban conditions and the protection of labour e.g. tea-plantations, mines, railways, hydro-technical work, and other special conditions.

It is the work of Major Sinton and his assistants on the treatment of malaria which, in determining the best method of treating cases and preventing relapses, <sup>(18)</sup> shows once more the *importance of the treatment of the sick in malaria*.

We are convinced that the education of the sick by giving demonstrations of treatment in the villages would soon persuade all those who are prejudiced and would fulfil the purpose of curing the sick.

*Treatment by quinine* (and in a few cases *prophylaxis by quinine*) is carried out in all the anti-malaria centres described in paragraph C. During our visit, we always attached great importance to this question; at times, our guides laid special stress on this point; at others we were hardly given time to think about it since our whole attention was directed to anti-larval measures. Nevertheless, quinine was always given and affected the frequency of malaria, if only because of the fact that all those who have fever can obtain quinine easily and at the moment they require it. Moreover, we were glad to find that the inhabitants, whatever their prejudice, sought quinine when they had fever, even if they abandoned the treatment as soon as they thought they had recovered. This fact ought never to be forgotten when considering the examples of anti-malaria work which we cite in this report. (See Fig. 17.)

Under present conditions, intensive treatment is only given in the treatment centre at Kasauli, and at certain European hospitals. At Mettur-Dam, where medical treatment and hygiene are so well organised, a malaria epidemic was stopped at the Salem camp, and the splenic index reduced from 47 per cent to 7 per cent by treating the sick for three weeks and also by giving quinine as a preventive. On the other hand, at the Krishnaraja Sagara Dam, under the Mysore Government, even in the hospitals, malaria patients were only given the following amount of quinine:

	Quinine lb.	Cinchona febrifuge lb.
In 1925 for 4,897 patients . . . . .	7	10
In 1926 for 4,776 patients . . . . .	11	10
In 1927 for 3,447 patients . . . . .	5	—
In 1928 for 4,130 patients . . . . .	10	5
17,250 patients . . . . .	33	25

This gives an average of 0.86 grammes of quinine and 0.60 grammes cinchona febrifuge per patient. The treatment lasted as a rule three days and quinine was distributed by the dispensaries.

*Measures against anopheles* consisted of anti-larval measures only.

We did not see any examples of *measures directed against the adult anopheles*. Yet when we saw how simple coolies in tea-gardens were able to distinguish, not only anopheles, but even the "Mini-macha",<sup>1</sup> we felt that perhaps an opportunity had been neglected especially in the case of stone-built white-washed coolie houses, where the catching of mosquitoes is rendered much easier. We recommend this catching of mosquitoes at least for a trial.

Screening, as a measure of anti-malarial control, we saw only in a few instances.

The anti-larval measures consisted chiefly of oiling. An important point is supervision, but we think the statement is somewhat exaggerated that every coolie in India requires a man to supervise him and that the supervisor has to be watched by someone else. We realise how the caste system in India, which restricts operations like oiling to the very lowest classes, renders anti-larval work more difficult than anywhere else; nevertheless, we have seen oiling and other anti-larval measures well executed and therefore know that they are practicable.

The kind of oil used differs from place to place, but the special product called "Pesterrine M.D.B.", sold by the Burma Oil Co. at 8½ annas a gallon, is extensively used. Other types are mixtures of crude oil with "solar oil" or with kerosene. The spraying is done with pressure sprayers or with watering-cans. Drip-cans and substances soaked in oil, (oil-balls, oil-guddas, oil-swabs) deposited in the water to allow of a constant supply of oil are frequently in use.

With regard to paris green, we may be allowed the following remarks in a separate paragraph:

#### PARIS GREEN.

Paris green is the cheapest and most easily applied of all larvicides. In India, it costs twenty annas a pound, whereas oil is only ten annas per gallon. But from five

<sup>1</sup> This was the name the coolies used to indicate *A. minimus*.

to twenty gallons of oil are needed per acre, whereas never more than one pound of paris green. Oil is two and a-half to ten times as costly as paris green. Along ditches and small streams, a load of diluted dust will cover many times the number of feet covered by the quantity of oil procurable for the same cost and can be applied at a more rapid rate. Over ponds and swamps, if advantage be taken of winds and stronger percentages used, the work of oiling can be replaced by paris green in one-twentieth the time and with about one-tenth the number of man-hours. Why, then, is so little use made of paris green in India? <sup>(19)</sup> The answer is twofold: the difficulties of application under Indian conditions and the human factor.

These difficulties can best be shown in reviewing some examples. In the large pools in the Bombay reclamation area wherein *A. culicifacies* abounded, paris green has been applied by coolies from a raft in a 1 % dilution in sand. One coolie pushes the raft over the whole pond surface, while another dusts by hand. These pools are now oiled, as the ditches had been, by coolies with knapsack sprayers. At Mian Mir, three men waded through all parts of a two-acre pond blowing from small bellows a 1 % paris green mixture in road dust on to every square yard of water surface. For the ditches in the vicinity, oil was used. At Birnagar, one coolie paddled a boat downstream, while two in the bow threw handfuls of 1 % paris green in wood ashes towards either bank. In the Moghal gardens of New Delhi, a 1 % paris green mixture in sand is applied daily to all the water-troughs and ornamental tanks; the ditches outside the gardens are oiled. Oil is here the larvicide of choice, because it can be seen, while paris green is used in the gardens only because it does not stain the concrete.

Further, at Bombay and Mian Mir, no advantage was taken of a favouring wind, as the diluting dust was too heavy and the percentage of poison too weak. In the Birnagar experiments, most of the pools lying near the streams received little or none of the dust with enough paris green to be effective. At New Delhi, the percentage mixture was correct and the heavy dust excellent, for no drift by wind is needed, but, owing to the human factor, all collections of water had to be dusted each day, otherwise, if dustings were weekly only, every breeding-place carelessly missed would produce a disastrous crop.

In Cachar (in Assam tea estates), oil was used instead of paris green, for oil leaves obvious traces and the dust leaves little or none. Although labour may be the most costly item in other countries, it is the cheapest in India. The impression prevails that the extra cost of supervision to insure proper dusting by coolies is too great and that such supervision would be more costly than the labour saved by changing from oil to paris green. The same view prevails at Meenglas, where the area beyond the field drains is controlled by larvicide application.

The Birnagar authorities realised that a better diluting dust than wood ashes was needed and that a 1 % mixture was too weak; at Mian Mir they had found road dust a variable substance, sometimes light and powdery, blowing away in the wind, sometimes heavy with sand and not spreading at all; at Siliguri different percentages are being tried, bellows are replaced by blowers, and soapstone is the diluting powder. However, it is difficult for those supervising control work to do very much research.

Of the greatest importance is the research into the application of paris green by the "Malaria Survey" of India.

This organisation has begun field experiments on the uses of paris green at Karnal. They wish to determine the best diluent dusts for use in India, both for streams and swamps; what is the best percentage of dilution of paris green for practical purposes; what is the best apparatus; what is the best method of employing labour; and how much supervision is essential. Some of these questions will require long observation, but it seems certain that the most important will be solved at no distant date. Then, perhaps, this easy method of controlling the production of anopheles may come into more general use among those workers who now pin their faith on oil. Its method of application might, perhaps, be so cheapened as to come within the reach of many villages and towns where *nothing* is now done; gardens such as at Madaya might become less of a problem; more towns in the Bengal delta might practise this method as a temporary expedient while awaiting resuscitation of their rivers and a return of flood irrigation; the pits of the casuarina groves of Ennore might be rendered harmless at little cost, and a drifting cloud of paris green might prove a happy preventive of malaria breeding in many paddy fields. There are exceptional paddy fields which are now complicating malaria control work. We saw an example at Siliguri, where a 5 or 10 % cloud is to be drifted over growing rice; another at Dangooposi, where oiling may not be done and removal is impossible. In Delhi, in Bombay, in Lucknow, we were shown where great obstacles confronted those who wished to prevent breeding of *A. stephensi* in wells, and suggested a pinch of paris green for each well; in the shaded streams of Cachar, we were shown open areas in deep ravines where the cost of oiling was prohibitive. Here, as in Rayagada Gorge, we thought paper bags of paris green could be thrown to burst on the steep bank or rocky shores. Although the use of paris green is in its infancy in India, it shows signs of a rapid growth, and further experiments will prove whether it is destined to play an important rôle in Indian anti-malaria work.

### C. CONTROL OF MALARIA IN AGRICULTURAL, INDUSTRIAL AND MILITARY CENTRES.

We consider this form of malaria control separately, as it offers possibilities which naturally do not exist among an ordinary rural or urban population. Consequently, the experience gained here cannot be applied elsewhere without due regard to the differences in physical and economic conditions.

#### 1. CONTROL OF MALARIA AMONG WORKMEN IN TEA-GARDENS.

##### (a) *General Medical Aid (Treatment by Quinine) and General Sanitation.*

The tea-gardens we have in view here are situated in the foot-hills or in the lower hills of the southern slopes of the Himalayas (Terai, Duars in Bengal)<sup>(20)</sup> or on the northern and

southern slopes of the Assam Hills. <sup>(21)</sup> The more important gardens employ a number of coolies varying from 1,000 to 2,000 or more. They are usually not local people but are recruited elsewhere from Chota-Nagpur, Cuttack and the "Agency" in the north of Madras Province, the Central Provinces, etc., often from more or less malarious districts. They are completely free to leave whenever they like and an opportunity to do so is always offered them by the allurements of the native gardens, freely interspersed between the European ones, where they are not worried by sanitary supervision, quinine treatment, model houses and the like. The manager of a garden must be very careful, consequently, not to frighten his coolies away and to make his garden as attractive in their eyes as possible. This must be borne in mind when in some of these gardens the coolie lines are found in a state which must awaken in the labourer's breast a feeling of intense homeliness, in ours a feeling of disgust. But we feel full of admiration for the owners of other gardens where the medical department has created excellent houses, latrines, a water supply and other sanitary arrangements, which they hope in time will find favour in the coolies' eyes.

One of the great attractions of a tea-garden is the rice-fields attached to it, which are ceded to the coolies at a nominal rent. The more rice-fields a garden owns, the easier it is for the manager to procure coolies, but the more difficult to make them work for the garden except in the season when the rice-fields require no attention. Still, importation of labour is so expensive and garden-bred labour is so much more satisfactory in the long run, that it is every manager's ideal to have his own local colony of labourers born and bred on his estate. As the rice-fields are a material help towards this end, he accepts them with all the disadvantages their presence involves. So does the medical department, notwithstanding the fact that these rice-fields, at any rate their feeding and draining channels, often produce dangerous breeding-grounds. (See Figs. 18 to 21.)

The usual anophelis breeding-places in these areas <sup>(22)</sup> are the hill streams, wherever they do not run too fast, and the eddies, pockets, seepage areas, swamps or impounded tanks in their course: The drainage ditches and borrow-pits in the gardens are equally dangerous, even if the water is stagnant, provided it is clear. *A. minimus*, *A. listoni* and *A. maculatus* are the principal carriers.

The medical department in every garden consists of an Indian "sub-assistant-surgeon" in charge of a small hospital with 5 to 6 or more beds (the number of beds is hardly more than 1 per cent of the population) and a dispensary with a compounder. Sometimes there is a second dispensary with a compounder if a portion of the garden is situated at a distance from the main garden ("out-garden"). The duty of the Indian sub-assistant-surgeon, assisted by his compounder, is to find out and to treat the sick. The hospital and dispensary are at an easy distance from the coolie lines, even from the "out-gardens", and the coolies do not get sick pay unless they apply for treatment. There can be no doubt that the discovery of cases, even of incipient cases, and the treatment of malaria is as good as it ever can be hoped for among free labourers who refuse to take the medicine as soon as they cease to feel ill and run away to a "native garden" if they are worried too much.

This system of medical aid to the labourers (and to their whole family we should be careful to add) is supervised by a European medical officer who has under his care a

number of gardens (e.g., 18) sometimes belonging to two or more companies. His duty is to visit the hospital in every garden regularly once or twice a week. In severe cases, the local Indian sub-assistant-surgeon calls him in for consultation and he is, moreover, in charge of the whole European staff of the gardens, and of their families (about 50 persons or more.)

As all these duties, and especially the daily tours of inspection, practically occupy all his time, it is remarkable that several of these European superintending medical officers still find time to occupy themselves with sanitation and social hygiene, including maternity welfare, which is so important for colonisation, and is therefore accompanied by liberal pre- and post-natal facilities for mother and child. Notwithstanding the system of quinisation, perfect under the existing circumstances, there are even medical superintendents who go as far as to tackle anti-larval control. This, however, has only recently begun, except in one instance that we have seen (we understand there are others) where this control had been continued for several years. We will deal with this separately.

The medical attendance and supervision involves an annual expenditure which in a model garden amounts to 10.2 rupees per head of the working members of the Indian population, not including capital outlay and the salary of the medical superintendent.

#### (b) *Anti-larval Control.*

For the benefit of the malaria control in the tea-gardens, the Public Health Department in Bengal has founded an experimental station in the tea-garden Meenglas (Duars).<sup>(23)</sup> This garden is protected on one side by thick jungle. When we say "protected", we mean: (1) that this jungle, over a mile in breadth, is supposed to prevent anopheles penetrating the protected estate from an unprotected one lying beyond the jungle; (2) that the hill streams passing this jungle need no supervision until they emerge in the open and traverse the estate. (See Figs. 22 and 23.) For it is a common experience now (Strickland) that hill streams breeding *A. minimus*, *A. listoni* and *A. maculatus* in the open do not do so when they are shaded by heavy jungle.

In this estate, the coolie lines are protected by converting into subsoil drains all the streams ("jhoras") within half a mile from the human habitations; as this proved to be insufficient, the radius of protection has been extended to one mile by oiling the remainder of the streams. The cost, since 1917, has been 34,000 rupees. Local opinion holds the results to be satisfactory, a reduction of 40 to 70 per cent in the spleen rate having been noted since 1917. Unfortunately, these results are not constant, as our own examination showed a spleen rate of 89 per cent among the children of this estate and of 82 to 87 per cent in some adjoining estates where work of this kind, executed by the same personnel, had been taken up recently.

One of the reasons of these unsatisfactory results is believed to be that the radius of protection (half a mile, later extended to one mile) is too short. This opinion is in striking contradiction with the experience gained by Ramsay in a number of tea-gardens in Cachar (Southern Assam) at the edge of the Surma valley, to which we have referred already in some detail when discussing the malaria conditions in Lower Bengal. The

anti-larval work carried out here by Ramsay is a splendid example of a *pure species sanitation*. Almost 30,000 anopheles were dissected and action was taken on the basis of the results, which showed only *A. minimus* to be infected.<sup>1</sup> The work, moreover, is based on the biology of this species with the change of its breeding-places ("summer resorts" and "winter resorts"), and deals with the summer resorts only. Finally, it is based on the experience gained during the first two years, showing that the complete abolition of all "summer resorts" by oiling, filling in or draining within half a mile of the coolie lines, reduced the spleen rate from an average of 70 per cent to an average of 30 per cent after one year and to 4 to 13 per cent after two years, whereas unprotected coolie lines showed no reduction, or even an increase. This experience convinced Ramsay that, under the conditions prevalent in his gardens, a range of flight of *A. minimus* of over half a mile need not be taken into account. (See Figs. 24 to 26.)

In the eighteen estates under his supervision, with a total population of about a thousand each, it has been possible in two or three years' time to reduce the spleen rate from 70 to 10 per cent, to double the amount of labour done by the same number of coolies and to reduce greatly the quantity of quinine dispensed. This has been done at an expenditure of about 1 rupee per head.<sup>2</sup> But it should be borne in mind that Mr. Ramsay, by possessing a central hospital to which all severe cases were sent, was freed of the worrying duty of rounds of inspection.

## 2. CONTROL OF MALARIA AMONG THE PERSONNEL OF RAILWAY STATIONS.

We have seen some examples of protection of the personnel of railway stations and their families by treatment, which can, of course, be done much more easily than among an ordinary population. This is especially the case in Siliguri,<sup>3</sup> where ten grains of quinine was administered prophylactically thrice a week. We were struck by the fact that 70 per cent of the population took the quinine regularly. Oiling and paris greening was also done. The sick rate decreased from 40 to 17 cases per month in August, September and October.

But the most important examples of this kind were found along the Amda Jamda line in Singhbhum (Orissa)<sup>(24)</sup> (Bengal Nagpur Railway), notorious for the enormous toll of sick and dead from malaria during its construction. The railway company, taught by this experience, has spared no cost to protect the personnel of the stations, this being the only means of keeping the line, which is particularly important because of the iron and

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<sup>1</sup> *A. ramsayi* was also found infected in one particular instance; but, as the finding does not change the situation, we leave it out here.

<sup>2</sup> It is hoped that this expenditure will be further reduced if the experiment to prevent breeding of *A. minimus* in drainage ditches, streams and swamps by planting shrubs and trees giving a heavy shade proves successful.

<sup>3</sup> We regret to hear that the railway company concerned is about to abolish the post of malarialogist, a most unwise policy in our opinion.

manganese mines in the area, in working condition. Dr. Senior White, <sup>(25)</sup> the malariologist of this company, has succeeded in doing so by anti-larval measures within a radius of half a mile round the stations.

The work practically consists in dealing with all possible breeding-places (hill streams, seepage areas, swamps and drainage ditches, even concrete ones, borrow-pits, etc.) by oiling, sometimes combined with a preliminary training of the banks of streams. The oiling is very carefully done, as is shown by the fact that the treated streams and ditches show a yellow edge of dead grass and no vegetation except for a matting of cyanophyceæ at the bottom of the ditch. The costs are comparatively heavy. In one station, they were 12,000 rupees capital outlay and 2,500 to 3,000 rupees annually to protect a personnel of 461. But, in cases like these, they are not prohibitive. The half-mile radius proves quite sufficient, but it should be remembered that a large portion of the breeding-places are artificial "man-made" and are especially numerous close to the protected area. Further away they are much less numerous, except for rice-fields, and these are not particularly dangerous unless seepage occurs through the bunds or unless they contain springs. If these fields are dangerous, their presence may actually frustrate any practical attempt at protection.

The protection of the railway area in Waltair, conducted along exactly the same lines, costing 3,637 rupees annually to protect a population of about a thousand, is particularly convincing, as the total sick rate of the protected population never rises to 1 per cent monthly, whereas the personnel and families living outside the protected area show a sick rate of at least 8 per cent in the malaria season, although the medical attendance is the same for both.

In both these instances, the anophelines responsible were the usual hill stream breeders: *A. listoni*, *A. minimus* and *A. maculatus*.

### 3. CONTROL OF MALARIA AMONG THE WORKMEN ON A RAILWAY UNDER CONSTRUCTION.

We have seen a particularly instructive instance of this kind of work in the construction of the Vizianagram-Raipur line of the Bengal-Nagpur Railway, which was carried out under the direction of Dr. Senior White. This line runs through the valley of the Nagavali, which used to have a reputation of being highly malarious. A preliminary survey showed a high spleen rate (60 to 80 per cent and higher) among the villages inhabited by a mixture of Telugus and aboriginal tribes. The anopheline fauna was of the usual hill type, the principal carrier being *A. listoni*; *A. culicifacies* was limited to larger streams. The duty of the malariologist was to indicate the sites of the future labour camps, which should be so situated as to render their protection by anti-larval measures as sure and easy as possible, without interfering with the work. These two, often irreconcilable, requirements—a camp site might be found near the work, but surrounded on all sides by extensive seepage areas, or else in a nice dry place but at too great a distance—had constantly to be borne in mind. The result was that a number of camps could be protected



at small costs, only a few streams having to be regulated and oiled within the half-mile radius which was taken here, as elsewhere, as the standard limit. In other cases, stream-beds had to be regulated and seepage to be dealt with, necessitating sometimes the application of hundreds of oil swabs (waste-cotton drenched in crude oil and applied at the source of each small seepage stream, or fixed with a wooden peg in the cracks of a rock or slope from which the seepage water was running down).<sup>1</sup> Swamps were treated with paris green. One of the worst places, Chatikona, headquarters of the second district and of the future "summit" station, required oiling of 53,979 linear feet of drain and trained stream, and paris greening of 2,621,798 square feet of land which had been made boggy by uncontrollable seepage, at a total monthly expenditure of 750 rupees, to protect a staff of 250 and 265 coolies. The worst feature was that the heavy breeding continued unchecked outside the limits of the treated area, rendering it more than doubtful whether the half-mile radius in this instance was really sufficient. At any rate, the sick rate, due to fresh cases of malaria, was not high—less than 1 per cent per month. In some other neighbouring camps, where the contractor refused to carry out the prescribed anti-malarial measures, the sick rate ran so high (we unfortunately did not collect the actual figures) that the coolies were deserting one after the other and the work in these camps had stopped completely. Information regarding these unsatisfactory conditions was naturally welcomed by us as affording some insight into the actual value of such costly measures. Without such information, a sceptical critic might have maintained that the work would have gone on as well without all that oiling and paris greening.<sup>2</sup> The discomfiture of the contractor, who evidently shared the views of the critic, is sufficient answer to the criticism.

#### 4. CONTROL OF MALARIA AMONG THE CLERICAL AND MECHANICIAN PERSONNEL OF MINES.

Here we have in view the protection of the European and of the Indian clerical and mechanical staff of the iron and manganese mines along the Amda Jamda Railway. (26) Protection of the subordinate workmen is not possible, as they largely consist of aborigines who refuse to live within the protected area, and either return to their own villages at night or collect in constantly shifting camps. (See Figure 27.)

Since the country is the same as that through which the Amda Jamda Railway runs and the anti-larval work is organised and supervised by Dr. Senior White, as consulting malariologist to the mining companies, the work is essentially the same as that round the railway stations. It is directed against the hill stream, seepage and swamp-breeding anophelines, and takes the form of oiling, regulating the beds of streams and occasionally drainage of minor swamps.

The costs, to protect about 300 inhabitants in one of these mines, amounted to 17,984

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<sup>1</sup> As a matter of curiosity, we may note that old swabs used for some time for cleaning machines and drenched with machine oil containing particles of copper and iron are the best.

<sup>2</sup> Total cost to protect the camps alongside the 60 miles of railway within the danger zone, 57,600 rupees in four years, being 0.48 per cent of the total costs of the construction of this portion of the line.

rupees (non-recurring costs on capital) and a monthly expenditure (salaries, labour, oil) of 1,640 rupees.

##### 5. CONTROL OF MALARIA DURING THE CONSTRUCTION OF PORTS.

Of this kind of anti-malarial work we have seen one important example, executed during the construction of the port of Vizagapatam (destined to become the best harbour of the east coast).<sup>(27)</sup> In the swampy brackish plain to the west of the town, to be occupied largely by the harbour, there breeds only *A. subpictus* and fortunately no *A. ludlowi*. The danger zone is the foot-hill area bordering this plain to the north and south. The hill streams coming down in numbers all breed *A. listoni*, and where they enter the plain they produce swamps which remain dangerous till they reach the central area of brackish water. The town itself is not free from malaria owing to the breeding of *A. culicifacies* in three streams and of *A. stephensi* in almost 70 per cent of 700 wells. Oiling of the nullahs, regulating their banks and an ingeniously constructed open hillfoot drain, which has rendered almost completely harmless the nullahs of the southern hills, thereby greatly reducing the costs of oiling, constitute the main features of the anti-larval work. It will protect the bungalows of the senior port officers, the site of which is planned at the foot of the southern hills. For this purpose, the villages which were situated here, and which showed high spleen rates, have all been removed and the inhabitants collected into one village to the west of the protected area, which itself is partly protected by oiling the neighbouring nullahs.<sup>1</sup> The senior officers' bungalows in the hills along the coast north of the town are protected by regulating and oiling the nullah there.

This work, which shows its good results by the declining number of malaria cases treated in the hospital<sup>2</sup> of the port, is of particular interest, because it has been undertaken, not as a consequence of a serious outbreak of malaria, but to prevent such an outbreak among the present labour force and especially among the personnel of the port after it has been opened.

It is the more to be regretted that all this carefully planned and admirably executed work may be rendered useless by the almost complete inaction of the municipality of Vizagapatam and the adjoining district boards, which leaves this town and rural area a constant threat to the health of the harbour. The usual excuse for inaction—lack of money<sup>3</sup>—cannot be considered serious, since the town is bound to profit immensely from the opening of the new harbour.

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<sup>1</sup> The spleen rate of this village we found on December 4th to be 31 per cent only and 28 per cent in February. Unfortunately, another village at the foot of the northern hills, quite near an untreated nullah where many mosquitoes breed, showed a spleen rate of 35 per cent. It is therefore difficult to conclude that the low spleen rate of the former is due solely to anti-malaria measures taken.

<sup>2</sup> The comparatively low rate of malignant tertian, 23-25 per cent in 1927-28, suggests that quinine treatment is not without its influence.

<sup>3</sup> The more preposterous, as the self-governing bodies do not hesitate to levy heavy taxes on the railway and the port trust, while they leave it to these authorities to carry out sanitary precautions which should properly be taken by the municipality and district boards.

More than anywhere else, we were struck here by the wisdom of the Government of Mysore's plan to centralise under the Public Health Department all sanitary powers vested at present in the local self-governing boards—which have amply shown themselves unfit for their task, at least in this respect.

#### 6. CONTROL OF MALARIA DURING THE CONSTRUCTION OF IRRIGATION WORKS.

We have seen three of these works. From the malaria point of view, the construction of the headworks of the Sarda canal (28) on the Sarda river on the frontier of Nepal are the most important. Anti-larval work, drainage and oiling close round the labour camps, combined with quinine treatment carried out by six health officers working in two hospitals, has within a period of nine years much reduced malaria among a labour force of from 3,000 to 9,000 coolies in this foot-hill area of the United Provinces, where *A. listoni*, *A. culicifacies*, *A. maculatus* and *A. minimus* are the chief carriers. We understand that the work has proved particularly beneficial in restoring confidence among the better class labour contractors, who at first, after a disastrous outbreak of malaria in this notoriously unhealthy country, refused to work. Moreover, it induced the coolies to stay in the country each year for a month longer than usual.<sup>1</sup> The sick rate has dropped considerably, but we cannot say whether the area was much less malarious than before, as we found the spleen rate among 50 coolies 98 per cent in October; but with the constant coming and going of the labourers such a figure has little value. (See Fig. 28.)

The Metur-dam works on the Cauvery river (Madras Presidency), although in a less malarious country, have produced a far more interesting problem. In the original villages in this area, now occupied by the works, the spleen rate was 45 per cent at its maximum. This, again, is a foot-hill country with, however, curiously enough, only *A. culicifacies* as a carrier. Round the works, the coolie lines are built mostly of stone with due regard to sanitary requirements, with an excellent water supply and sewage disposal, model latrines and bathing accommodation. (See Fig. 29 to 34.)

The total population, including coolies' families, varies from 15,000 to 17,000. (29) The medical department has a hospital with 36-72 beds. The sanitary department is under a health officer, with six sanitary inspectors who are wholly or partly in charge of anti-malaria work, assisted by four "Mistris" (assistant inspectors) and a gang of 30 coolies. The mistris, in their daily rounds through the coolie lines, detect persons suffering from or showing preliminary symptoms of fever (headache, etc.), make blood-slides and distribute quinine to those found by blood examination to be suffering from malaria. The daily dose is 20 grains for three weeks. If a number of cases occur in one camp within a short period, as happened in three different camps in three succeeding years, the sanitary inspectors

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<sup>1</sup> The labour force, largely recruited in Bundelkhand, return home every rainy season and remain at work from November till the middle of May only. Now they are persuaded to stay on till mid-June.

themselves distribute quinine as a prophylactic to all inhabitants exposed to infection—every week on two consecutive days 10 grains, continued for one and a half months. In these circumstances, 80 to 85 per cent of the population take this prophylactic quinine regularly.<sup>1</sup> In addition to the curative and prophylactic dosing with quinine, anti-larval work is done by regulating the banks of various nullahs, by controlling seepage with herring-bone or contour-drains and by oiling the nullahs and water channels. Oil swabs, again, prove very useful placed at the head of small channels. Drip-cans, on the contrary, have proved unreliable if used as a substitute for spraying oil.<sup>2</sup> The Cauvery River itself was very difficult to handle. The numerous pools along the main bed were oiled, but the breeding of *A. culicifacies* in the stream itself remained uncontrolled.

The result of the work is shown in the low malaria rate of 1 to 2 per cent of indigenous cases per year, and the low spleen rate of 19 per cent in the camp, which this same year had suffered from an outbreak of malaria. The cost of maintaining the whole of the sanitary department is 30,000 to 35,000 rupees per annum,<sup>3</sup> of which 12,000 rupees are spent on anti-malaria coolie gangs and oil.

The Metur dam will impound a lake of 59¼ square miles for irrigation purposes. The level of the lake will be subjected to great variations. What the results of this impounding will be on the malaria conditions in the surrounding country is a point which does not so far seem to have attracted any attention. It is to be regretted that no study has been made in this respect of the impounding of Krishnaraja Sagara on the same river Cauvery, within the State of Mysore. It is an irrigation lake of 32 square miles, liable also to great changes of level.

#### 7. MALARIA CONTROL IN LAHORE CANTONMENTS. (MIAN MIR).

This was of particular interest to us; first, because Mian Mir had been the site of the first anti-larval work done in India by Christophers and James; secondly, because, this place was the only one we saw where screening, combined with the killing of those mosquitoes which succeeded in making their way inside the barracks, was regarded as the main protection against malaria among the European troops. The results seem very satisfactory, as there was a great reduction in the malaria incidence, but it was pointed out to us that this did not conclusively prove the efficiency of this measure, as the last two years had been very dry and only slightly malarious. Anti-larval measures, although still continued to some extent, were not considered to have caused this reduction.

Judging by the results of anti-larval measures carried out elsewhere, the failure of the anti-malarial campaign in Mian Mir may seem very remarkable.<sup>(30)</sup> Certainly, the wide extent of cantonment to be protected, the miles and miles of drainage ditches to be oiled

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<sup>1</sup> See Chapter II, paragraph B.

<sup>2</sup> Drip-cans were useful in Vizagapatam, but only to *supplement oil-spraying*, especially during the rainy season.

<sup>3</sup> Being 0.04 per cent of the total cost of the work.

and the numerous breeding-places outside the treated area, look formidable, but they are really no more formidable than, say, the conditions in and round Delhi or Saharanpur; and in those places results have been attained without much difficulty.

We are not satisfied with the explanation that the work in Mian Mir is badly done. We do not believe that the oiling and cleaning here was inferior to the average work of this kind done to-day.

And, as a matter of fact, results were obtained by the anti-larval work and thorough treatment of the cases among the soldiers. It was as difficult to decide then as it is now which of these two forms of work was most important. We are convinced that if this work had been in progress at the time of our visit, we are sure that it would have been shown to us as just as successful a piece of work as, for example, the protection of the labour camps in Metur or at the head-works of the Sarda Canal.

What Mian Mir showed was that this kind of work as carried out by Christophers and James cannot be done cheaply and easily and that, as soon as it is stopped, the results are quickly lost. We do not believe that recent anti-larval work carried out under similar circumstances has in any way disproved the soundness of this "lesson of Mian Mir".

#### D. CONTROL OF MALARIA IN CITIES AND TOWNS.

##### 1. IMPERIAL PROVINCE OF DELHI.<sup>(40)</sup>

The most important malaria control of this kind that we have seen was in the urban and suburban area of the Imperial Province of Delhi. Genuine co-operation between the health authorities of Old Delhi of the civil lines, the "notified area", and of New Delhi, has led here to a notable reduction of the spleen rate both in the city proper and in the suburbs. This is the more remarkable since the malaria conditions in villages in the neighbourhood but outside the treated area (half-mile radius around the protected quarters) show no improvement. Some of them at any rate show high spleen rates (over 60 per cent). (See Figs. 35 to 39.)

Part of the problem here is purely urban (*A. stephensi* in wells), the treatment of which is attended by the same difficulties as in Bombay, though the health authorities here seem to be more successful in overcoming them. Outside the old city, malaria is transmitted by *A. culicifacies*.<sup>(31)</sup> Some of the breeding-places formed by the flooding of the Jumna (Bela area) have been effectively dealt with by filling of pools between Old Delhi and the river. Many depend on irrigation in fruit gardens in Sabzimandi quarters. Other breeding-places are due to the defective irrigation of the old Najafgarh-Jheel, by the Najafgarh cut in which there is stagnant water, and to stagnant water in the Khudsia and Metcalfehouse creeks. The breeding-places resulting from these are effectively dealt with by cleaning, regulating the banks, stone-lining, cunetting of channels and oiling. A constant supply of oil is maintained by the use of oil-balls and oil-pillows

soaked in oil (oil gaddahs) and anchored or fixed in the bed of the streams. Water-logging due to the Jumna river, aggravated probably by the Okladam, south of Delhi, still gives much trouble. The western Jumna canal, branches of which traversed the city, has been directed outside this area. All this work is by no means completed. In fact, so much still remains to be done that one wonders whether all these excellent results are due only to the careful, but very incomplete, measures or whether the last two dry years have not been a considerable help to human efforts. *But undoubtedly all the work performed has been necessary and has been well done.* And if the expenditure—less than four annas per head—of the whole public health department of the imperial province, excluding Old Delhi, be considered, the expenses of anti-malaria work cannot be judged excessive.

We can ignore the anti-malaria work in New Delhi—an area with a low malarial incidence but threatening to become malarious because of the construction of ornamental tanks—and will treat in the next paragraph the work of sanitation in the rural areas of this province. <sup>(32)</sup>

## 2. SAHARANPUR.

Next of importance as an example of malaria control in towns is Saharanpur, where malaria has been reduced from a 79 per cent spleen rate in 1909 <sup>(33)</sup> to 7.3 per cent in 1923, and to 3 per cent in 1929. We were assured that the high spleen rate in 1909 was not the result of an epidemic rise of the malarial incidence, but that it represented a constant figure in this area and that this rate is still found in the villages around the town, which did not profit by the anti-malaria work. As a matter of fact, we found a spleen rate of 82 per cent in one of them.<sup>1</sup> The work has been done at a cost of 350,000 rupees in 15 years, amounting to 6 <sup>1</sup>/<sub>4</sub> annas per head of the population per year. In this case, as in a few other towns in the United Provinces where similar work has been carried out, the Government and not the municipalities paid for it.

The actual anti-larval work, which consists in stone-lining the drainage ditches and the two streams which traverse the town and in filling in some important breeding-pools, is strictly limited to the town area and a few furlongs outside it. Moreover, canal irrigation is prohibited within a radius of one mile, wet cultivation within a radius of three quarters of a mile round the town.

## 3. LUCKNOW.

In Lucknow, the malaria in the outskirts of the city depends on breeding in the Gumti and the Hydercanal. The latter has been cunetted and connected to the former, and a very interesting system of weekly flushing of the former has been introduced. Whereas the spleen rates in the outskirts had dropped from 18 per cent to 10 per cent, possibly owing to these measures, that of the central wards, which was formerly 3 per cent, has risen to from 30 to 40 per cent this year, a rise ascribed to breeding of *stephensi* in wells.

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<sup>1</sup> Although Saharanpur is a town, the malaria problem, depending on *A. culicifacies*, is rural. Consequently, results can be compared with those in the neighbouring villages.

#### 4. BOMBAY.

Malaria conditions in Bombay have been sufficiently described in discussing the *A. stephensi* problem in general. We need not insist on a history of all the attempts to carry out an efficient malaria control. Up to the present they have failed, not through want of sufficient knowledge or of means to carry them out, but through a deplorable lack of co-operation between the various authorities, through religious objections which must be respected in so far as they are sincere and not a weapon in the hand of politicians, and through agitation in certain sections of the Press, which would appear not to be aware of their great responsibilities.

#### 5. BANGALORE.

We can only hope that the sanitation of Bangalore, a city which has likewise its *stephensi* problem, with its 2,660 wells, 75 per cent of which are breeding, will show the way to all the cities in India that are struggling against this difficulty and help them to deal with it effectively. At present we can say no more, as the anti-malaria campaign has only just begun there.

### E. CONTROL OF MALARIA IN RURAL AREAS.

Of this we have seen practically nothing. The nearest approach to it is the malaria control in Hsipaw<sup>1</sup> and Lashio<sup>1</sup> in the North Shan States (Burma), which may be regarded as fairly large villages, and that of Ennur to the north of Madras. All these cases chiefly interest us as a manifestation of the desire of the public health authorities to attack malaria outside the larger inhabited centres where no great economical interests are at stake, *i.e.*, malaria as it exists in 90 per cent of the malarious areas in India.

#### 1. HSIPAW.

In Hsipaw, in the valley of the Namtu, a hilly area 1,300 feet high, where *A. minimus* and *A. culicifacies* are the chief carriers, measures against breeding, such as oiling and training of the banks of streams, abolition of rice-fields near human habitations, have been taken. But numerous breeding-places are left untreated, because they are impossible to treat with the limited financial means. It is therefore difficult to attribute the reduction of the spleen rate (from 50 per cent to 40 per cent) to these measures, since nothing is known concerning the change in the spleen rate in the outlying villages.

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<sup>1</sup> Reports (not yet published) by E. S. Feegrade.

## 2. LASHIO.

(See Fig. 40.)

In Lashio, north-east of Hsipaw, on a plateau at a higher altitude (3,000 feet) with the same malaria vectors, the problems are essentially the same as in Hsipaw and in all hilly country. Since in this place there will be 10,000 rupees available annually for the next five years for anti-malarial work protecting 4,000 inhabitants, a system of drainage of seepage swamps has been carried out, together with jungle-cutting to render the existing streams and seepage areas more accessible and to increase evaporation, which by itself often proves sufficient to dry a certain number of seepage areas which remain in existence as long as they are covered by jungle.<sup>1</sup> The reduction of the spleen rate from 33 per cent to 23 per cent in the town proper, including civilian and police lines, and from 55 per cent to 43 per cent in the neighbouring rural areas, is encouraging, since it shows that quinisation which does not affect the rural areas, but is thoroughly carried out in the town, is not wholly responsible for it. But whether the anti-larval measures are responsible is equally doubtful, since there are no control areas.

## 3. ENNUR.

The coastal villages in and behind the low sand dunes north of Madras present an interesting malaria problem, which we mention here and not under the heading of research, since a deliberate attempt was made to prevent malaria.<sup>(34)</sup> This attempt, however, was discontinued when the area came under self-government. (See Fig. 41.)

In the sand dunes there are casuarina plantations of about one hundred acres on every 2½ to 5 square miles of dunes. As the young casuarina trees require careful and frequent watering for the first 2½ to 3 years of their cultivation, water is obtained by digging wells in the sand. Every acre of forest is said to contain from 30 to 40 of these pits.<sup>2</sup> When the pits are no longer required, they are left as they are without being filled in. When seven years old, the trees are felled and sold as fuel at a price of 28 rupees per ton.

These pits breed *A. culicifacies*, and no other water in this whole area is supposed to breed them, neither that in the rice-fields and tanks which serve to irrigate them nor the natural, shallow, weedy pools in the lower parts of the sand dunes. Stephens and Christophers long ago proved *A. culicifacies* to be the sole carrier there. A splendid opportunity is thus afforded to carry out species sanitation and at the same time to right

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<sup>1</sup> The method of clearing the jungle here is contrary to that employed in Bengal and Assam, where the maintenance or planting of thick jungle is used as a measure against *A. minimus*.

<sup>2</sup> In a plantation of six-months-old trees of three acres, we actually counted only six pits in December.



an obvious wrong, for the people suffering most from malaria are the fishermen whose villages on the dunes are nearest to the plantations. The farmers and the people tending the trees live further away and suffer less, and the owners live in Madras and suffer not at all. The opportunity has been recognised and then neglected, and things are left as they were before.

## F. POPULAR EFFORTS TO CONTROL MALARIA.

These are the most hopeful of all, even if they should prove inefficient for the moment. The great point is that they should be carried out in the right spirit, *i.e.*, that they should be the result of a sincere desire to rid oneself and one's neighbours of a disease which has been recognised as an evil which is not inevitable.

Some of these movements are really governmental and are intended to render the people interested and secure their active help. The least elaborate form is that of simple propaganda by posters, pamphlets, and sometimes cinemas.

### 1. IMPERIAL PROVINCE OF DELHI.

In the rural areas of the Imperial Province of Delhi, the villages have been induced to request the local district boards to instal a "panchayat" (village council of five) in each village. This council is expected to carry out the necessary sanitary measures with funds raised in each village. Advice is given by public health officials, a sanitary guide and two sanitary assistants for every "zail" (six to ten villages). For the present, this system exists only in one zail and its results cannot yet be judged.

### 2. UNITED PROVINCES.

In the United Provinces, active propaganda is carried out by boy scouts and others. We saw a "malaria film" and in a village near Lucknow a "Malaria drama" performed by the village schoolboys, the point of both being to persuade the people to have their fever properly treated. (See Fig. 42.)

To render this treatment possible, since under average circumstances most people cannot get treatment within reasonable distance, so called "school dispensaries" have been instituted in 36 villages, where the schoolmaster dispenses simple medicines (partly *yayurvedic*,<sup>1</sup> but quinine at least is among them) to the school-children.<sup>2</sup> He visits them

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<sup>1</sup> Medicine according to prescription derived from the *Yayur Veda*.

<sup>2</sup> School quininisation has had the special attention of the authorities in the United Provinces as is apparent from Graham's (1910, 1911, 1913, 1914) and Harris' (1915, 1916, 1917) reports published by the Government of this province. The most recent publication issued by the Hygiene Publicity Bureau of the United Provinces is that by A. Sousa: "Village Aid".

when they are absent from school and, through them, he gets information about the health of the other members of their families, treats them if necessary, and even keeps a register of births and deaths among the families of his pupils. This is a very interesting attempt to raise vital statistics above the "chaukidar" level.

### 3. BENGAL.

The most interesting popular efforts we saw, however, were in Bengal—most important because independent of the Government.

The first consists in the formation of the "Anti-malarial Co-operative Societies"<sup>1</sup> and is the most wide-spread, comprising at present more than 2,000 societies under the slogan "All for one and one for all". It is wholly supported by contributions and donations and may be described as an association of sick-clubs, each club maintaining for two or three villages a dispensary. Moreover, each club, by a monthly subsidy, persuades a medical man to come and live in the village group and to treat the members of the club for half pay. The number of the members of such a club may be 400, one-third of the total population, the income 2,375 rupees, the expenditure (including a subsidy of 600 rupees to the doctor) 2,335 rupees.

Besides this medical work of the club there is sanitary work, which sometimes goes to the length of supplying water (100-200 gallons) to each member's house, an important anti-malarial measure as it renders tanks superfluous. Children are taught to do anti-larval work, but this part of the societies' activities we cannot consider as anything but purely educational. It might go further, however, if the societies more often obtained the advice of the public health department, which is never given spontaneously, but which they know full well they can have for the asking.

In this respect, the "Palli Mandali" of Birnagar, <sup>(35)</sup> a village of 2,300 inhabitants north of Calcutta, is better than these societies, for they have freely sought the Public Health Department's advice. As a consequence, their anti-larval work is on a much higher level than the others. But to the annual costs of 4,280 rupees for maintaining a staff of one sanitary inspector, six "sarkars" and six coolies, and for the oiling, cleaning, etc., the Government contributes 1,500 rupees and, in addition, 50 lb. quinine and 50 lb. cinchona febrifuge annually. Apart from supervising anti-larval work of the ordinary kind, the sarkars pay house-to-house visits to find cases of malaria and administer quinine. All the members of the families visited are registered on cards. Finally, six tube wells have been constructed for 15,000 rupees; two are paid for by the Government, one by the municipality whose total income is 7,000 rupees, and three by private gifts. (See Figs. 43 and 44.)

The fact that the Palli Mandali is unique of its kind, and the co-operative societies are numerous, makes us believe that the former represents an ideal of which the latter are the realisable form.

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<sup>1</sup> Annual Report of the Central Co-operative Anti-malaria Society. (There exist already 10 of these reports, of about 100 pages each.)

### G. SUMMARY OF CHAPTER III.

Anyone who reads this description of anti-malaria work cannot but be struck by the fact that the third section (c) takes up far the most space, although the actual description given is, if anything, shorter than those given elsewhere in the report. It really means that malaria control in India is practically limited to selected groups of the population, whose health, for some reason or another, is particularly valuable and particularly threatened by malaria. We have not seen any instance of an all-round malaria control in an ordinary village and remember that 90 per cent of the Indian population live in these villages, but we understand that experimental control has been undertaken in many instances.

It is difficult to say how far the experience thus gained can be used for the control of malaria in rural areas. With the present public health budgets and the inertia of local governing bodies, we doubt whether it will prove useful, as it only teaches that malaria can be controlled if sufficient money is available.

However, we do not doubt that much of the research work which has been done to prepare these anti-malaria campaigns will prove useful, once it has been discovered how malaria can be controlled in a village.

One of the most practical questions to be answered then will be: How far round the village shall the anti-larval operations be extended? The uniform answer derived from the experience at present accumulated is half a mile or even less, provided there are no large important breeding areas just outside this limit. This conclusion, which applies to *A. culicifacies* and the *funestus* group, is of the utmost importance, as it was often pointed out to us, particularly by Dr. Senior White, that anti-larval work would practically become impossible if the limit had to be extended for over half a mile<sup>1</sup>.

In many instances we feel convinced that the half-mile limit was sufficient to reduce malaria transmission by anopheles to such an extent, that the measures supported by quinine available to all attained the purpose for which they were designed—keeping the sick rate low enough not to interfere with the work and with the recruiting of labour.

But in some other instances—*e.g.*, Burma—we could not feel so convinced of this. We saw a reduction in the spleen rate after certain measures, but those measures were not so thoroughly carried out as to warrant the belief that it was due solely to them. Here we need an additional proof before we can recommend them to the future village sanitation: the proof that the reduction of malaria was limited to the treated area and was not a general symptom in that part of the country. Curiously enough, this proof, which should never be wanting in any attempt at malaria control carried out for experimental purposes, was often absent in the records of investigations carried out before and after

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<sup>1</sup> Of course, this applies to regions with numerous breeding-places, not to an area with one or two streams and the rest dry as dust.

the anti-malaria campaign. This, moreover, was not caused by lack of time or staff, for attention was being given at the same time to research work of a kind which, however interesting, was not of such importance that it might not have been dispensed with for the moment.

The Malaria Commission of the League of Nations has always stressed in its publications the need of adequate control in anti-malarial operations which are intended to furnish an example of how to carry out such measures in other places. It is a great satisfaction to the Commission to see that the necessity to comply with this requirement was fully realised and acted upon in India long before the Malaria Commission made its suggestion.

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## IV. RESEARCH.

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The distinction made here between research and control is totally artificial. Scientific research on malaria is always inspired by practical attempts to solve the problems these attempts bring to light. These attempts should always be accompanied, and when carried out for experimental purposes even *preceded, by research*. It is futile and even misleading to make a distinction between "practical" and "scientific". All practical work in malaria control should be done scientifically, *i.e.*, in a way affording a clear understanding of the relation between the conditions due to the factors introduced by the experimenter and the conditions not due to those factors. Any work which does not fulfil this requirement is not only unscientific, it is unpractical.

It is, however, possible to distinguish between research which has an immediate bearing on some local practical problem (all preliminary research preceding practical measures is of this kind) and research intended to solve fundamental problems. We may call the former applied research and the latter basic research.

### A. BASIC RESEARCH.<sup>1</sup>

The "Malaria Survey" of India is the natural home for basic research on malaria. Here we felt ourselves at home more than anywhere else, for we recognised the true British-Indian medium of malaria research that we had admired of old in the classical works of Christophers and his fellow-workers, of James, Bentley and others—the medium which has acted as such a stimulant both to research and to practical application in other parts of the world, where research workers continue to look gratefully to "Mother India" as the source from which they derived so much inspiration.

Leprince<sup>2</sup> has said that "the British have done much more intensive survey work, but that it has not been so closely confined to the determination or devising of new, better, cheaper and quicker control measures as have the investigations of Americans". In a way, we may agree that he is right, but let us remember that Indian investigators have paved the way for the discovery of these measures. And if anyone complains of too much research and too little application, let him remember the magnitude of the problem compared to the relatively simple ones elsewhere.

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<sup>1</sup> We do not repeat here what is contained in Chapter II, which is all founded on the basic research of Gill, Bentley, Covell and others.

<sup>2</sup> *Southern Medical Journal*, 1927, XX, No. 6.

But let us return to the present situation at the headquarters of the Malaria Survey of India in Kasauli and its field station in Karnal. Here are studied the two media of the malarial parasite, man and mosquito, and the influence of the human factor<sup>(36)</sup> and the anopheline factor on the epidemiology of malaria. At present, the latter has the larger share of the attention of research workers. How could it be otherwise in a land where the “*anopheline factor*” shows such an infinite variation in form? This variation is daily increasing, for a minute study shows that some of the present anopheline species are indeed composites embracing a number of minor but well distinguished and constant sub-species. This is a common experience in every group of plants and animals studied in minute detail. Such a study often leads to hair-splitting and the worship of futilities, if it is carried on merely for its own sake. But here the investigators in Kasauli and Karnal are hygienists using entomology only as a means to serve their end. They know that not all anopheline species are of the same importance as malaria transmitters, but they also know that in addition to species which never, and others which always, transmit malaria, there are some which do so in one area and fail to do so in another. The riddle of anophelism without malaria, so puzzling to older investigators, found its preliminary solution when Stephens and Christophers showed that some species are infected in nature and others are not. But this primary differentiation, although still holding true in principle, is no longer sufficient. Anophelism without malaria occurs not only within the range of distribution of the genus *Anopheles*, but likewise within that of one single species, and the question therefore arises: “Is this species which we consider a unit really a homogeneous species or is it a compound species?” That consideration, and not merely systematic interest, has led to the revision of the systematics of Indian anophelines, to the creation of numerous new species and to the raising to the rank of valid species of forms recognised up till now as hardly more than doubtful varieties. A striking example of the value of this work is the fact, brought out at the experimental station in Krishnagar in Lower Bengal, of the special importance as a malaria carrier of *A. philippinensis* over the two other members of the *fuliginosus* “group”. It is not unlikely that this analysis will have to enter into still more minute details, including biological differences, and that in this way it will be possible to explain the harmlessness of the autumn breeding forms of *A. minimus (varuna)* in the healthy plains of Eastern Bengal and of the Surma valley. The study of the minor species may not be a proper occupation for the botanist or the entomologist (according to Karl von Linné’s famous dictum), but it opens up great possibilities for the hygienist. That is one thing which the “Malaria Survey” of India teaches by its work.<sup>1</sup>

So long as the power to apply anti-larval measures is limited in India, *treatment of malaria remains an all-important point*. The discovery of the best method of treatment, including testing the value of new drugs and the most suitable way of distributing quinine

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<sup>1</sup> We cannot attempt to quote all the modern literature referring to this subject. Most of it has been published in the *Indian Journal of Medical Research*. Three papers, one by Christophers (*Ind. Med. Res. Memoirs*, No. 3, Dec. 1924) and two by Covell (*Ibidem*, No. 5, February 1927, and No. 7, July 1927) seem to form the base of this line of research.

in rural areas, may well be counted among "basic research". The first has been done among British soldiers suffering from constant malaria relapses and sent up for treatment to the special hospital in Kasauli.<sup>1</sup> The second will be, no doubt, an object of special enquiry in the numerous villages surrounding the field-station in Karnal.

The testing of the different known methods of *anti-larval* control, to find the ones best adapted to local conditions, is a third subject for basic research, eminently suited to the conditions present at the Karnal field-station; this has already been taken up by the staff.<sup>(37)</sup> The long continued observation of malarial incidence, of anopheline density in adults and larvæ, etc., in selected villages will permit a clear judgment on the comparative merits of the various methods and on their practical applicability under existing physical, social and economic conditions of a typical north Indian village. This research will settle the vexed question whether any measures of this kind are feasible in the rural areas of India or not.<sup>2</sup> If in nothing else, it will help in time to stabilise and to strengthen the anti-malaria policy of this Empire, which is still somewhat uncertain in its aims.

Moreover, these basic researches, by throwing light on the inter-relation between *malaria epidemics and economic conditions*, apart from the direct interference of the anopheline factor, will greatly help to confirm or to change the anti-malarial work in areas like the Punjab, where epidemic malaria plays the most important part, especially if they elucidate the part played by "*endemic foci*" as the starting-point of epidemics within the areas periodically subject to the latter.

That most interesting but far from solved question of the *relationship between malaria and blackwater fever*, has long engaged the attention of the workers of the "Malaria Survey" of India. This problem is a very practical one, as it is the existence of blackwater fever which renders malaria such an extremely serious disease in some of the hills and foot-hills.

The cases of blackwater fever with *Pl. falciparum tenue* which Sinton<sup>(38)</sup> studied by means of blood tests carried out every fifteen minutes enabled him to watch the evolution of this form of parasite and to adduce strong arguments in favour of his theory concerning the etiological rôle played by *Pl. falciparum tenue* in blackwater fever.

Finally, there is the question of *complete acquired immunity, among aboriginal tribes in hyper-endemic areas* in hills or foot-hills, which is shown less by a great reduction of the spleen rate than by a condition of general good health among adults. We have already referred to this subject on page 44. We do so again here because we feel that the problem is still unsolved, since we doubt whether the current views on this point are

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<sup>1</sup> Cf. Sinton, *loc. cit.* on page 48.

<sup>2</sup> It will settle, among other things, how far anti-larval work has to be extended outside the area to be protected. We members of the Commission who, by our experience in Europe, Africa, Indo-China and Malaga, are wont to deal with far-flying anopheles where a radius of three kilometres (nearly two miles) can hardly be deemed sufficient, always found it somewhat difficult during our tour in India to trust in anti-larval work on the half-mile basis. We gladly admit that in many instances it would have been hypercritical on our part not to accept the convincing evidence. Still, we should feel grateful if special investigations into the range of flight could be taken up.

correct and since we have found that the logical consequence of these views is inaction, except for work done to benefit an immigrant labour force. Our own very limited and incomplete experience has led us to believe that the malaria conditions in a population born and bred in hyper-endemic areas in British India in no way differs from the conditions we know exist in other places—the Dutch East Indies, for instance. The spleen rate is high both in adults and children, although the degree of splenic enlargement is less in the latter. If a marked difference between the spleen rate of adults and children exists anywhere at all, it is not found associated with very high rates (over 90 per cent), but with lower ones.

We do not doubt that a certain degree of immunity exists in areas where malaria is endemic, as shown by the lower parasite rate of the adults. But we are not yet satisfied that sanitary inaction in such a country is the best policy and we feel that more research is necessary before such a course is justified. On the other hand we realise that it should not be rejected without due consideration.

Basic research is not limited to Kasauli and Karnal. The workers in the *Krishnagar experimental station in Lower Bengal* actively contribute to the research and will do so more by elucidating the causes of anophelism without malaria in that country—causes which are still in many ways obscure. They will find great help in the researches of Dr. Ramsay in Assam on this subject, whose many thousand dissections, although undertaken for purely practical purposes, must certainly be counted as basic research.

Senior White's work<sup>1</sup> on the feeding habits of anopheline larvæ and the factors determining their thriving or waning should be mentioned here as fundamental for establishing biological control.

The *experimental stations in the State of Mysore*,<sup>(39)</sup> jointly maintained by the Public Health Department of that State and the Rockefeller Foundation, work on the same lines as the Central Malaria Survey with regard to basic research preparing the way for purely rural malaria control in India. This work is all the more valuable as it is done under conditions which differ vastly in almost every respect from those prevalent in northern India. (See Figs. 45 and 46.)

This has no pretensions to being an exhaustive summary, nor even approximately so. It gives only a resumé of the basic research with which we came into personal contact and of the lines which, we believe, it is following.

## B. APPLIED RESEARCH.

All practical measures, supervised by a trained observer, are, or lead to, applied research; consequently, we might refer the reader to Chapter III. But practical measures

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<sup>1</sup> Progress towards the realisation of biological control of mosquito breeding. Seventh Congress Far Eastern Assoc. *Trop. Med.*, Vol. II, Calcutta, Dec. 1927.



carried out with the express object of collecting experience to be used later when similar measures are applied on a larger scale, with little or no opportunity for preliminary investigations, should indeed be called applied research. We have seen several instances of this kind, especially in the province of Burma. Although not quite up to the level of scientific thoroughness with which the Central Malaria Survey must be credited, these investigations are highly valuable, as they tend to fill the great and obvious gap in our knowledge of the methods of anti-malarial control best suited to rural areas.

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## V. SUMMARY AND CONCLUSIONS.

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We began this report by stating our difficulties in following the lines of our previous reports because of the absence of a general system of malaria control, not only throughout the whole of India, but also in each one of the various provinces. We have seen admirable research on malaria control, but we cannot help feeling that malaria control in India should be very much more actively prosecuted as a general duty by the public health departments, and that the control of rural malaria should be taken up more seriously.

In some provinces, however, it is evidently in the making, and unless the constant danger in India of discontinuity of purpose intervenes, due to a change in the senior staff, we may expect Burma to establish a wide spread system of rural health units, ensuring adequate medical treatment and a certain amount of sanitary control, among which we may expect to find anti-larval measures. In the United Provinces, where experimental centres like those in Burma have not developed, but where the school treatment flourishes in selected villages, we may expect this system to develop further, perhaps in the direction of popular work along the Bengal lines.

In Bengal, very much depends on the adoption of Bentley's scheme, which, apart from its direct consequences to anopheles, may be expected to raise economic conditions and stimulate popular action, leading to an extension of the co-operative societies and the establishment of an adequate rural medical service all over the country.

In the Punjab, it may be expected that the further development of rural public health work will lead to an improved quinine treatment in rural areas. In the State of Mysore, the great number of dispensaries even now ensures a better quinine treatment than anywhere else in India, and with the establishment of health units the system will be improved still more.

There is no doubt that an adequate quinine distribution cannot stop at ensuring the presence of a sufficient quantity of quinine in every village. It will have to see that the people who need it obtain it free of charge or for payment according to circumstances, even if they do not ask for it. *Without quinine distributors, quinine distribution is almost useless.* But with this system in the hands of the Public Health Department, the latter encroaches somewhat on the domain of the Medical Department. Moreover, the latter's dispensaries and their sub-assistant surgeons are of such obvious importance in this scheme that it may well be asked whether the result will not be either an uneconomical duplication of work or a gradual fusing of these two departments in rural areas. *The latter course seems the more reasonable, i.e., a transfer of all rural medical assistance to the Public Health Department, leaving only the large hospitals in the cities to the Medical*

Department. This would involve the further advantage of giving the Public Health Department a stronger hold on the population, which is at present not sufficiently educated to appreciate prevention of disease, but is still in the "dramatic" stage which likes to see cures. *A rural public health department in India should cure and should therefore discharge likewise the functions of a medical department. The distinction between these two departments, perhaps suitable for European conditions, appears to us wrong in principle in India.*

How far the rural health service can be improved and supplemented by a system of medical assistance and to what extent the need for quinine treatment can be eliminated by anti-larval measures will greatly depend on the result of the basic research, dealt with in the preceding chapter. It is impossible for us to venture any prediction as to the future of this branch of sanitary work in rural India. We can only express the hope that any plans of this kind will not be abandoned before they have been given a fair trial.

We trust that the rural area in the imperial province of Delhi will set an example, just as Old and New Delhi are now doing in respect of urban areas. The provincial Governments can be of great assistance in establishing demonstration centres for larval control in selected villages, of the type which already exist for urban areas in towns like Delhi and Saharanpur. The demonstration centres of the "Malaria Survey" (Karnal) may be expected to collect much valuable information which will become available to all, *if close co-operation can be established between the provincial public health departments and the "Malaria Survey" of India.*

In the past, we understand this co-operation has been hampered by administrative difficulties, but we do not doubt that they will be overcome now that the importance of such co-operation has been recognised. We do not feel justified in making any recommendations, as they should come only from the Malaria Survey of India and its experimental station at Karnal.

Finally, we are certain of one thing. Public health work is much hampered by lack of funds. Unless there is more money available, either by increasing the provincial public health budgets or the contributions from the local boards, we fear that anti-malarial work cannot be extended. Public health has been transferred to self-government. Consequently, the people, who elect their representatives, can provide public health or not as they like. It seems that, in this way a heavy responsibility has been laid on the shoulders of the people; it has to be faced, and it can be faced in one way only: rendering the task easier of accomplishment by educating the young receptive minds in the schools. *The future of public health lies in the hands of the younger generation.*

All the foregoing remarks refer to rural areas in the conviction that rural India is far more important as regards malaria than urban India. Much of what has been said may be held to apply to urban areas likewise, but as the population is denser and the revenue larger the problem is easier from a financial point of view. Here, however, other difficulties appear, not to be met by popular education and propaganda alone.

The authorities themselves—the Central Government, the municipalities, port trusts, railways—have to be educated up to ensuring proper co-operation, the regrettable absence of which looms so largely among the causes of the failure of the *A. stephensi* campaign in a city like Bombay.

Although we adhere to our previous statement that rural malaria in India is the most important problem, we look upon it as a defect that the simple and clear-cut conditions of urban malaria have not been more controlled. If the people and the local boards in the city of Bombay could set aside personal feelings, political animosities and religious scruples, and could combine to drive out the enemy from a position that has only been tenable through mutual discord in the attacking force, we believe that a moral impetus of no mean value will be given to the rest of India.

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*Fig. 1.* — Breeding-places of *A. stephensi*: Well in a house. — Bangalore.



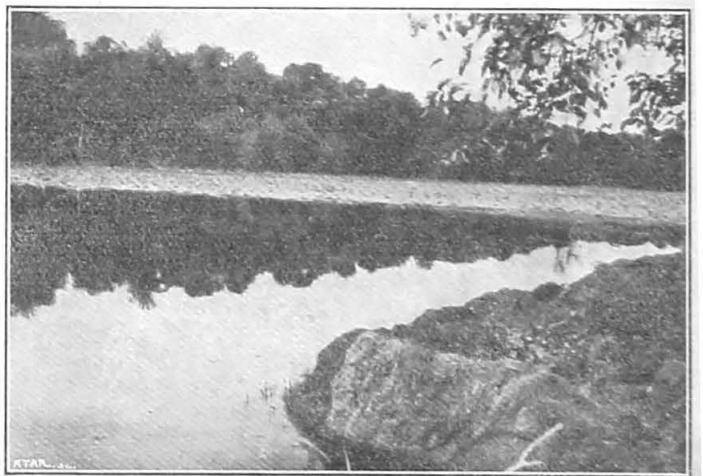
*Fig. 2.* — Breeding-places of *A. stephensi*: Vizagapatam. Wells.



*Fig. 3.* — Punjab: Chakanwali Farm. Waterlogged ground, into which a stick can easily be plunged.



*Fig. 4.* — Punjab, Chenab River: Breeding-places of *A. culicifacies*.



*Fig. 5.* — Bengal: Dead River.



*Fig. 6.* — Clear-water tanks. Typical malarious areas in Western Bengal.



*Fig. 7.* — Murshidabad. — Attempt to restore a dead river by conducting silty water from the Ganges.



*Fig. 8.* — Foot-hills areas: Singbhum-Uluburu. A "Nullah", breeding-place of *A. listoni*.

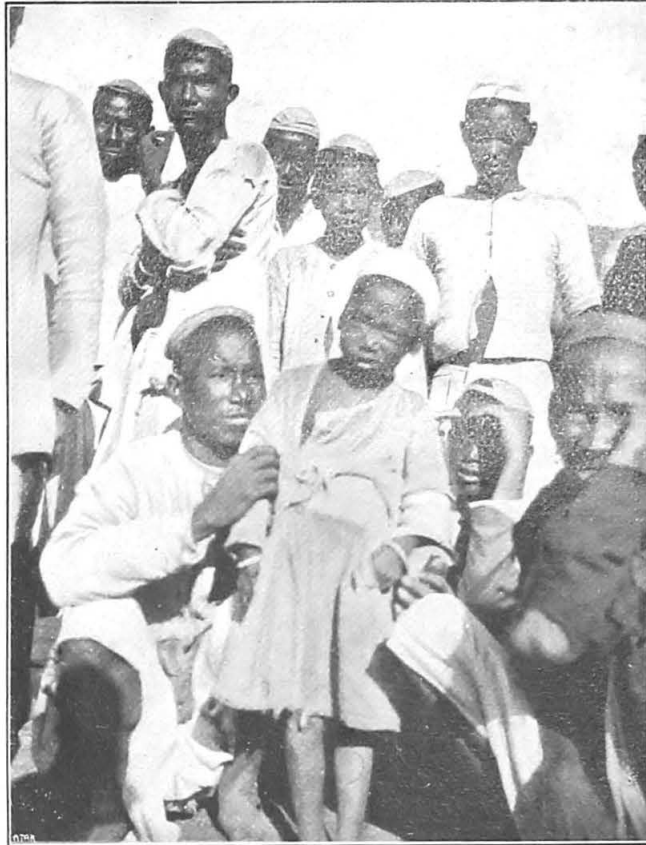


*Fig. 9.* — Foot-hill areas: Noamundi. — Breeding-place of *A. maculatus* and *A. maculipalpis*.



*Fig. 10.* — Foot-hill areas: Vizagapatam. — Vudu-Gaddah. Breeding-places of *A. listoni*.





*Fig. 11.* — United Provinces: A village of the “Buxas”, an aboriginal population proof against malaria.



*Fig. 12.* — United Provinces: A village of the “Tarus”, an aboriginal population with marked powers of resistance against malaria.



*Fig. 13.* — United Provinces: A “Daisi” child. Immigrant population heavily infected with malaria.



*Fig. 15.* — Karnal: Malaria survey in villages around Karnal.



*Fig. 14.* — Karnal: Breeding places around Karnal.



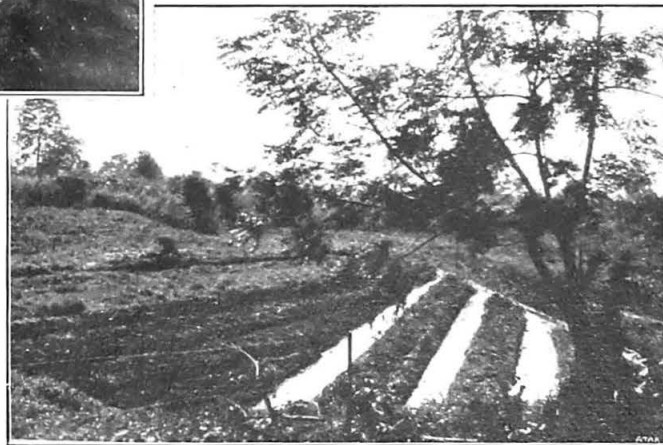
*Fig. 16.* — Karnal: Breeding-places of *A. culicifacies* — waterlogged ground.



*Fig. 17.* —  
Madras-Nadu wattam:  
A quinquina plantation.



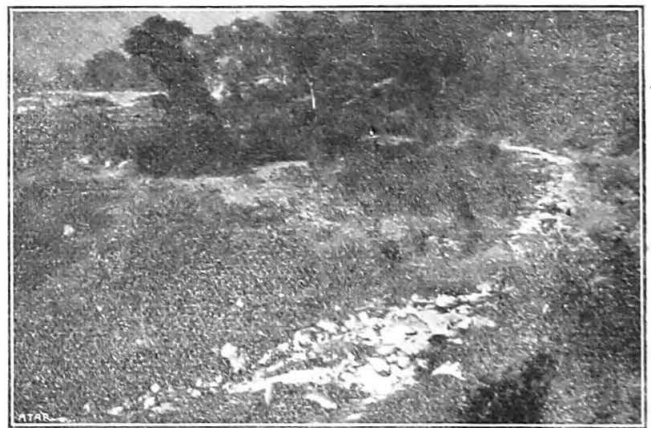
*Fig. 18.* — Tea plantation: A coolie line.



*Fig. 19.* — Tea plantations: Too extensive drainage system.



*Fig. 20.* — Tea plantations: Drainage canals  
in a coolie village.



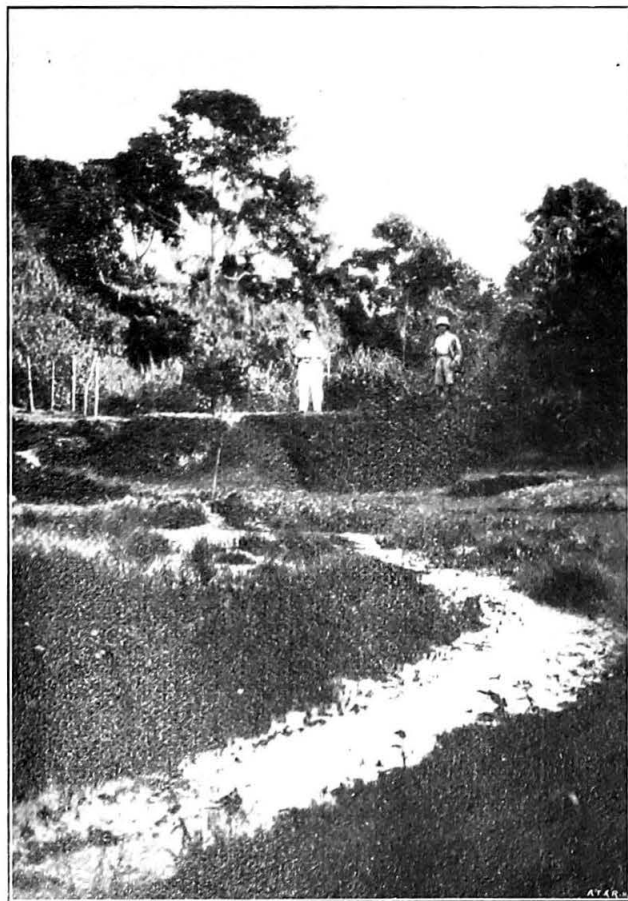
*Fig. 21.* — Tea plantations: Marianbari.  
Breeding-places.



*Fig. 22* — Meenglas Tea Estate. Flushing. Automatic courses in open drains.



*Fig. 23*. — Meenglas Tea Estate. Pukka ditch (must be oiled).



*Fig. 24.* — Cachar (Assam): Breeding-place of *A. minimus* after clearing jungle.



*Fig. 25.* — Cachar (Assam): Undrainable swamp, will shade with swamp growth. Tip of two weeks-old plant.



*Fig. 26.* — Cachar (Assam): Winter resorts of *A. minimus*.



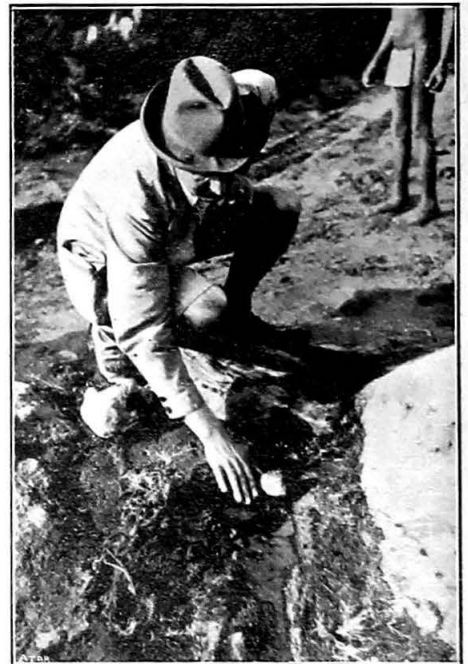
*Fig. 27.* — Singbuhm-Dangoposi.  
Breeding-places in close proximity to the protected area.



*Fig. 28.* — United Provinces: Drainage of the Sarda Canal.  
Bridge head at Banbassa.



*Fig. 29.* — Mettur: Salem Camp. A fine coolie village.



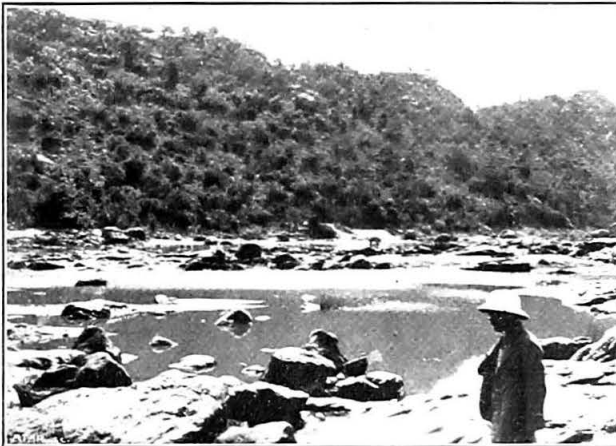
*Fig. 30.* — Mettur: Oiling the drains of seepage water.



*Fig. 31.* — Mettur: Drip-can oiling of drains.



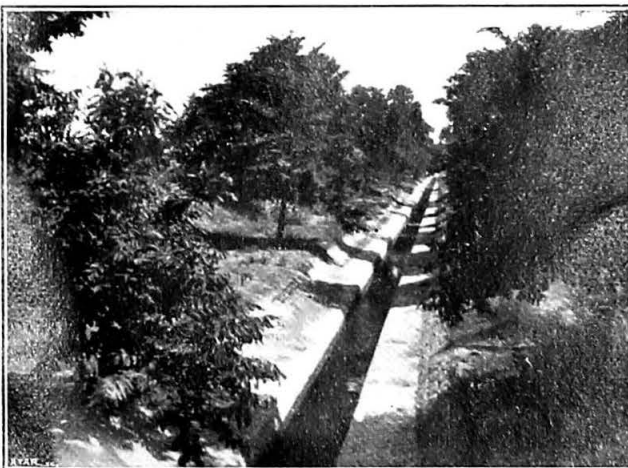
*Fig. 32.* — Mettur: Drainage of seepage water.



*Fig. 33.* — Mettur: Breeding-places of *A. culicifacies* in the bed of the river Cauvery.



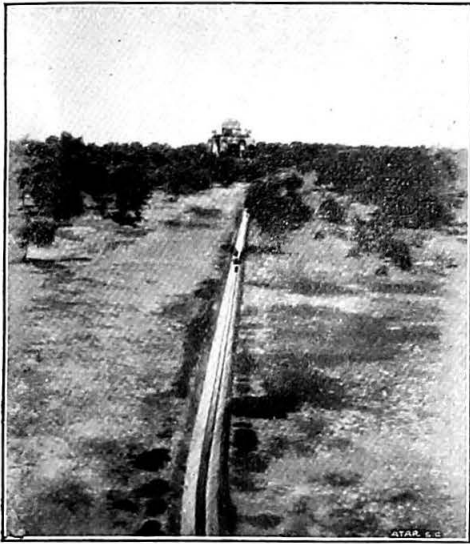
*Fig. 34.* — Mettur: Temporary coolie line.



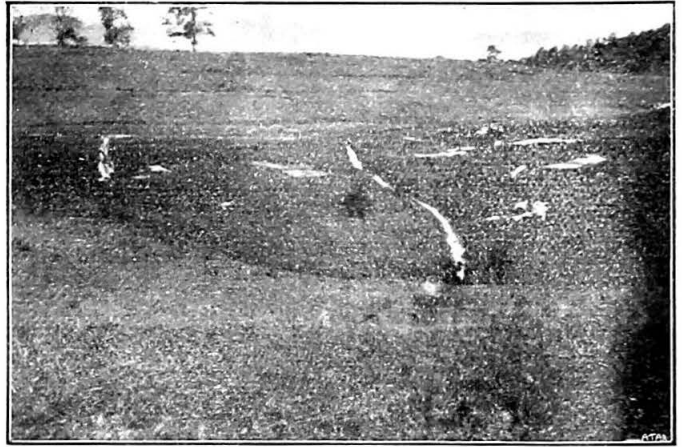
*Fig. 35.* — Delhi: Najafgarhcut cunnetted.



*Fig. 36.* — Delhi: Oiling open drains ("oil-guddah").



*Fig. 37.* — Delhi: Barapula Bridge. Open drain with central gutter. Dredging.



*Fig. 40.* — Lashio: Drainage system.



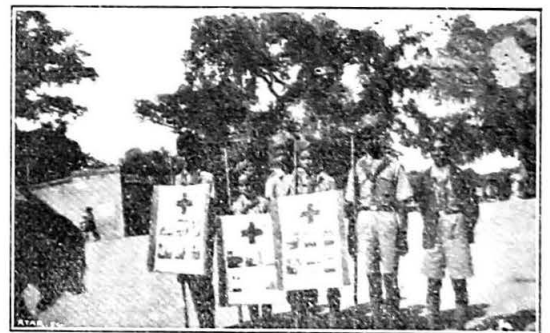
*Fig. 38.* — Delhi: Continuous oiling ("oil-ball").



*Fig. 41.* — Madras: Surface wells for casuarina crops.

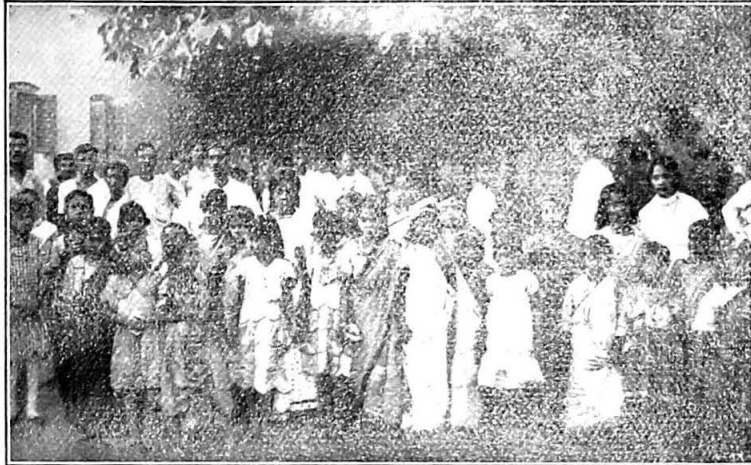


*Fig. 39.* — New Delhi: Consultation in a General Dispensary—Coolie lines

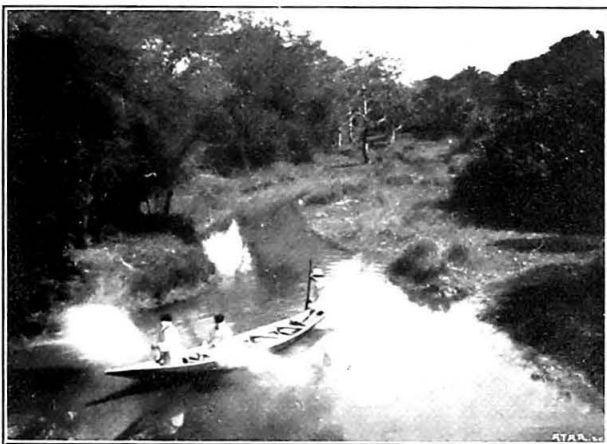


*Fig. 42.* — Saharanpur: Anti-malaria propaganda carried out by Boy Scouts.

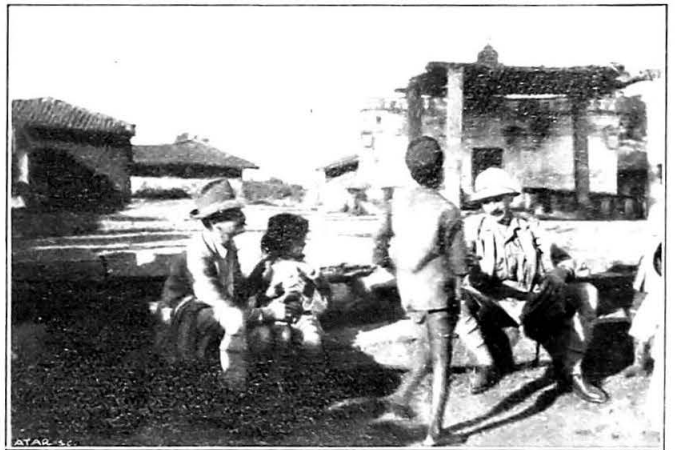




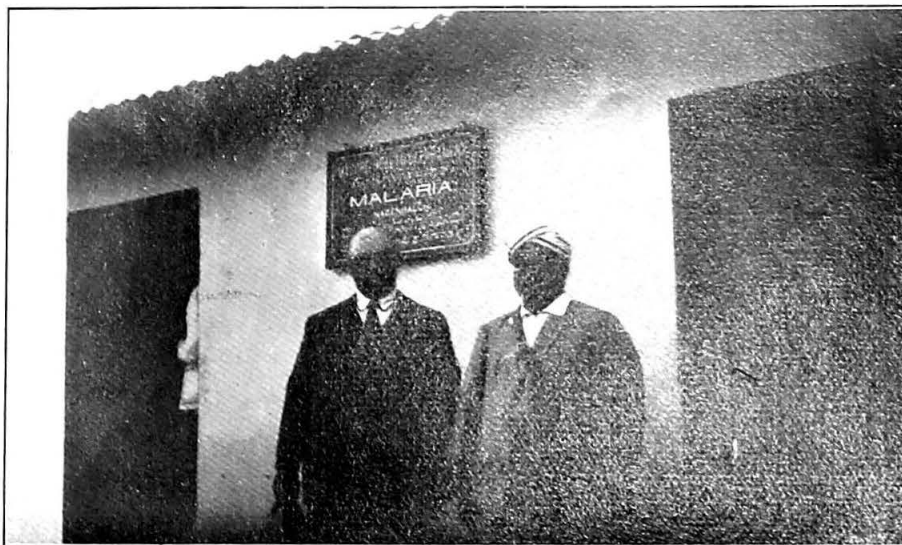
*Fig. 43.* — Bengal-Birnagar: The anti-malaria work of the "Palli Mandali". Group of children — treatment with quinine.



*Fig. 44.* — Bengal-Birnagar: Oiling a swamp.



*Fig. 45.* — Mysore: Nagenhalli. — Spleen index of children.



*Fig. 46.* — Mysore: Nagenhalli anti-malaria experimental station.