PROPHYLAXIS

OF

MALARIA IN INDIA

BY

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ERRATA.

Page.	Line			Correction	
47,	11th line from the	top	for	*labium*	read *labrum.*
57,	17th ,,	bottom	,,	*scutalaris*	,, *scutellaris.*
58,	19th ,,	top	,,	*hybernating*	,, *hibernating.*
58,	footnote		,,	p. 18	,, 178.
73,	3rd line from the	bottom	,,	tact	,, tract.
76,	20th ,,	top	,,	*palludism*	,, *paludism.*
76,	11th ,,	bottom	,,	*Nyss.*	,, *Myz.*
83,	2nd ,,	top	,,	*lindsayi*	,, *lindesayi.*
83,	7th ,,	top	,,	*Myz.*	,, *Nys.*
100,	18th ,,	bottom	,,	Shüffner's	,, Schüffner's.
108,	18th ,,	top	,,	25,000,000,000	,, 25,000,000,000.000.
118,	13th ,,	top	,,	is	,, are.
125,	7th ,,	top	,,	suction	,, action.
155,	8th ,,	bottom	,,	Dosag	,, Dosage.
178,	17th ,,	bottom	,,	Arizbna	,, Arizona.
193,	2nd ,,	top	after	"parts"	add as.
200,	20th ,,	top	for	walls	read wells.
201,	12th ,,	bottom	,,	plougng	,, ploughing.
220,	bottom line		,,	aive	,, give.
221,	3rd line from the	top	after	p.	add 250, 251.
223,	4th ,,	top	for	tabllets	read tablets.
223,	20th ,,	top	,,	251, 259	,, 250, 251.
224,	4th ,,	bottom	,,	capillalaries	,, capillaries.
227,	2nd ,,	bottom	,,	requires	,, requires.
228,	16th ,,	bottom	,,	an half	,, half an.
232,	14th ,,	top	after	instructions	add should be given.

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PROPHYLAXIS OF MALARIA IN INDIA.

SHORT HISTORY OF MALARIA.

Meaning of term MALARIA.—The term *Malaria* (It. *mala* bad, *aria* air) was first applied to a group of fevers having certain special characteristics about the year 1712. The term is unfortunate and etiologically incorrect, as at the time of its introduction it was believed that *miasmata* gave rise to malarial diseases of all kinds; and though it perpetuates an obsolete view, we are obliged from its antiquity to retain it. It has been ineradicably established in our terminology and its meaning is universally understood. The term is also applied to the special causes of malarial diseases, and to the combination of conditions that are required to bring those causes into operation.

Three chief discoveries in connection with malaria.—In the history of our knowledge of malaria there have been three dominating discoveries :—

(1) The discovery of the specific action of cinchona bark on malarial fevers, which goes back to the 17th century.

(2) The discovery of malarial parasites in the blood by LAVERAN in November, 1880.

(3) The discovery by RONALD ROSS that malarial parasites are carried from man to man by mosquitoes.

Discovery of cinchona bark.—Cinchona bark was introduced from Peru into Spain by the Viceroy del Cinchon and his physician Juan del Vego in 1640.

Anterior to the discovery of cinchona bark and its use in the treatment of fevers, malarial and other fevers were mixed up in the most confused way.

This first period in the history embraces (*a*) recognition of the action of cinchona bark in malarial fevers, and (*b*) the therapeutical specific division of fevers into the two classes—those that are curable by it and those that are not. In this latter work we are specially indebted to MORTON, TORTI and SYDENHAM.

On this foundation Torti wrote his classic account of malarial diseases. Clinically his descriptions excelled those of all previous writers, and remain up to the present a monumental record of his clinical and scientific acumen.

The abstraction of quinine from cinchona bark by the two chemists CAVENTOU and PELLITIER in 1820 marked another phase in the history of anti-malarial therapeutics.

The relationship of malarial diseases to the level of the subsoil ground water, and to meteorological and climatic conditions, was forcibly brought to notice by LANCISI, who also attempted to prove the connection of malaria with marshes experimentally. He remarks on the dark colour of the liver in fatal cases of malaria.

The rapid colonial expansion of European nations in the 18th century demonstrated the widespread geographical distribution of malarial fevers.

Discovery of malarial parasites by LAVERAN.—The second real epoch in the history of malaria was the discovery by LAVERAN of protozoal organisms in fresh blood in cases of malarial fever in Algeria in November, 1880.

LAVERAN began his inquiry by investigating the formation of pigment which occurs in malaria. He examined the blood of patients suffering from malaria and completed these observations in the dead body. He recognised that there were other pigment-containing bodies in malaria besides leucocytes, and first conjectured, and subsequently proved, that these bodies were the parasites of malaria.

GOLGI in 1885 confirmed Laveran's work and added largely to our knowledge of malaria. He formulated a series of laws which may be looked upon as classical. These are—

(1) That malarial parasites multiply in the blood by simultaneous sporulation.

(2) That the fever begins when the spores are liberated. [Fever ceases when all the spores have got into red cells.]

(3) That there are different varieties of malarial parasites.

He showed that the cycle of quartan was 72 hours, of simple tertian 48 hours. He had heard of " crescents " but had not seen them, and inferred that they were connected with a different variety of fever.

(4) That there are individual parasites in the blood which do not produce spores. These are now known to be *gametocytes*.

Shortly afterwards, MARCHIAFAVA, CELLI, and BIGNAMI, worked at the estivo-autumnal fevers of Italy. They demonstrated the characteristics of the malignant tertian parasite, and showed that the sporulating forms are seldom found in the peripheral blood.

Discovery of the mosquito cycle of malaria by Ronald Ross.— The real epoch-making step towards a scientific elucidation of the epidemiology of the malaria is due to Major Ronald Ross, I.M.S., who demonstrated the development of the sexual forms of malarial parasites in the stomach and body-cavity of the mosquito. This was suggested by epidemiological facts and certain phases in the history of the parasite indicating the necessity for alternation of generations, together with a change of host, as in other blood parasites of animals.

The forerunner of this theory was the finding of the *Microfilaria bancrofti* in the urine of man by T. R. Lewis in Calcutta in 1872, who afterwards found it in the blood of man. In 1884, Sir Patrick Manson traced the earlier stages of the development of the *Microfilaria bancrofti* to its parental form in the thoracic muscles of a variety of Culex. In regard to malaria Manson argued that mosquitoes rescue the parasites from the human blood vessels by sucking them out, and so offer them an opportunity for further development within their bodies. The manner in which this view, in a modified way, has been proved is dealt with later on.

Ronald Ross' work in connection with the manner in which the parasite of malaria was conveyed from man to man by mosquitoes will continue for all time to be one of the finest examples of scientific industry ever carried out in the hot climate of India.

A further advance was made by Macallum in 1897, who found that the full grown extra-corpuscular *Halteridium*, one of the avian malarial parasites, consisted of two forms, one which flagellated, and the other which did not. He found that the flagella, breaking away from the flagellated form, penetrated the non-flagellated organism, and after penetration, a motile body resulted which moved about among the blood cells. He saw the same phenomenon in connection with the sexual forms of the malignant tertian parasite.

Until about 30 years ago the cause of malaria in man was unknown, and up to 12 years ago the manner in which diseases associated with malaria were introduced into the human body was not ascertained. Investigations connected with the habits of mosquitoes and the methods of prophylaxis are continually being extended.

Malarial fevers, their nature and prophylaxis.—We now know definitely that *malarial fevers* are due to a class of protozoal organisms invading the red blood cells, destroying a large number of these cells during each attack of fever, and finding their way to certain tissues and organs of the body; that the products of these parasites give rise to the pathological and clinical sequence met with in all malarial fevers that may last indefinitely long; that this protozoon is introduced into the human blood by certain species of anophelines; that these mosquitoes acquire their infectivity from the blood of persons already the victims of malarial infection ; that quinine has the power of preventing the further development in the blood of the spores set free from the red blood cells during the first part of each attack of fever ; and that if given before a sufficient number of parasites are in the blood to create fever, quinine will, in the vast majority of cases, prevent such fever altogether ; and lastly, that by reducing the number of anophelines in malarious localities, we lessen the chances of their disseminating malarial infection in man.

PART I.—EPIDEMIOLOGY.

INTRODUCTION.

Economic importance of the malaria problem.—The prophylaxis of malaria is probably one of the most important economic and industrial problems of India. From the vastness of the subject and the numerous complex factors associated with the epidemiology of malaria in this country, the difficulties to be encountered in its solution are overwhelming.

Instances of successful localised anti-malarial campaigns.—Given a *limited* endemic malarial area to deal with and *unlimited* funds, any experienced malariologist could formulate a scheme for the reduction, and, in many places, the eradication of malaria in this country.

Panama Canal Zone.—We know that malaria and mosquitoes have been to a large extent eradicated from the Panama Canal Zone, Ishmalia, Klang and Port Sweatenham, and other localised places, and it has been argued that the measures employed in these localities are more or less applicable to India, and there is no doubt that were such measures, or some modification of them, *universally* brought into operation in this country, a very considerable reduction of malaria, and an appreciable reduction of anophelines would be effected. Whilst one recognises this and feels that every possible endeavour should be made to effect a diminution of the endemicity of malaria in India, one has to face the further fact that the reduction of malaria in an area of, say, five hundred square miles, is a very different matter to that of such reduction in the whole of the Indian Empire, which extends over an area of 1,870,000 odd miles. Let us take the Panama Canal Zone and inquire whether what has been done there is reasonably possible in any single endemic malaria district of, say, 50,000 square miles in area, in India.

In the Panama Canal Zone the anti-mosquito work of the Sanitary Department is considered to be of the greatest significance and is carried on universally over the whole zone area. The real canal zone is about 50 miles long and 10 broad. It includes, as far as sanitation is concerned, the cities of Panama and Colon. The zone population is about 100,000, which includes 33,000 in Panama, 14,000 in Colon, and 52,000 in the zone itself. In the zone there are a number of small towns and villages, with several native towns and camps for the executive and labouring staff between them, all of which lie along the line of the Panama railroad. Anti-mosquito work is carried on throughout the area covered by these towns and settlements.

The Sanitary Department has, aside from its office force, 30 Sanitary Inspectors, and employs between 1,200 and 1,300 labourers. With all due credit to the magnificent work and the undeniably brilliant results achieved, the work could undoubtedly be made more effective in some ways and less expensive in others through a more intimate knowledge of the mosquitoes concerned. Without entering into details it may be stated that all the known resources of the anti-malarial sanitarian have been employed. It is estimated that the sanitary works alone, excluding the upkeep of hospitals, costs about 15 lakhs of rupees a year.*

The construction of the Panama Canal has, however, been rendered possible by reason of the anti-malarial measures adopted by Colonel GORGAS, U.S.A. This was previously an impossible task on account of the high mortality from malaria and yellow fever.

Klang and Port Sweatenham.—These are neighbouring settlements in the Federated Malayan States, with a population of about 4,000. Anti-malarial measures, mostly consisting of drainage, were commenced in 1900—02. The admissions for malarial fever into hospital for the period including these operations is shown in the following table:—

Years.	*Cases.*
1901	501
1902	199
1903	69
1904	32
1905	23

In the surrounding district the disease has increased. The cost was £10,000 for initial permanent works, and £400 for annual upkeep in both towns combined, and for them as for Ishmalia, the medical officer reports that malarial fevers have now practically disappeared.

Ishmalia.—Ishmalia has a population of about 6,000 and is controlled by the Suez Canal Company. The malarial cases rose from 300 in 1877 to 2,250 in 1900. A campaign of drainage and treatment of old cases was commenced in 1902, with the following results:—

Years.	*Cases.*
1900	2,250
1901	1,900
1902	1,548
1903	214
1904	97
1905	37

* *Sanitary Regulations in the Panama Canal Zone*, by Mr. AUGUST BUSCH in the *Journal of Tropical Medicine*, August 15, 1908, p. 252.

Nearly all the cases in 1905 were cases of relapse among patients previously infected. It cost about £1,000 a year. The areas covered in the operations in this and in Klang and Port Sweatenham were comparatively small.

In all these instances practically all the known anti-malarial and anti-mosquito measures of modern times were employed. If we exclude the instances of the barracks of European Troops in the Island of St. Lucia, and that in the Island of Samarai (Papua), in which malaria was greatly reduced in the one case and eradicated in the other by drainage, and the eradication of malaria in a limited area in German East Africa by general cinchonisation, there are no recent instances on record of success in which any one system of prophylaxis has been relied on.

Are such successes to be expected in India?—The most sanguine and enthusiastic anti-malarial sanitarian could not devise any reasonable plan of campaign that would operate in the satisfactory manner it did in the places referred to, over an area of 1¾ million square miles. Under no circumstances is it conceivable that the same amount of concentrated energy and capital could be employed all over India. He might, however, reasonably hope to devise schemes that would considerably reduce malaria in the more endemic foci of this country, and his schemes would in all probability be proportionally much less costly, as labour and material are cheaper. But in effecting this salutary change in even comparatively small districts, he has before him an enormous undertaking.

PREVALENCE OF MALARIA IN INDIA.

Malarial statistics in India.—The first task before us in India is that of gauging the dimensions of the evil to be contended with. Whilst there are few malarial foci in India where malaria attains the same degree of intensity as it does, say, in the West Coast and in Tropical Africa generally, certain parts of Southern Italy and Sicily, Greece, etc., it may still be said that India is the most malarious country in the world. This is shown by actual statistics at our disposal.

If we exclude the malarial statistics of our larger public hospitals (which are so small that in the question of the general statistics of malaria in India they may be neglected), the only figures we can rely on are those published in the *Annual Sanitary Reports of the Sanitary Commissioner with the Government of India*. From these we conclude that on an average about 20 per cent. of our army in India suffers from malaria every year. Our troops are located in healthy barracks, well fed, have a staff of medical officers to attend them, hospitals in which to be suitably treated when ill, and, when necessary, they are given quinine prophylactically.

We have no statistics showing the malarial rate in the civil population in India; the nearest approach we have to it is the statement that about 5,000,000 people die annually from "fevers", of whom it has been roughly estimated that 20 to 25 per cent. succumb directly or indirectly from malaria. If the malarial fever rate of the civil population is the same as that in the Army in India, there would be at least 60 millions of cases a year. The probability is that in the rural population, poorly housed and worse fed, the proportion is much higher, and that there is in reality something like 80 millions of cases of malaria a year in the civil population. From personal experience one knows that the malaria of military cantonments is always less than that of the neighbouring civil community. At present, however, we are not in a position to estimate within many millions the amount of malaria in this country. There is not a single endemic malarial district in the whole of India regarding which we have even a rough estimate of the amount of malaria in existence. Probably about nine-tenths of the malaria of India is found in the population of villages. Probably not more than one-tenth of this number ever get quinine.

The following tables abstracted from the *Reports of the Sanitary Commissioner with the Government of India* give us an idea as to the extent to which malaria is prevalent in the Indian Army and in Indian Jails :—

Incidence of malarial fevers in European Troops in 1907 according to stations.—Admission rate for malarial fevers per 1,000 of strength amongst European Troops in the more important stations during the year 1907:—

Stations.	Strength.	Intermittent fever. *	Remittent fever. †
Port Blair	134	52·2	52·2
Rangoon	1,160	72·4	12·1
Bhamo	165	381·8	...
Fort William	1,342	104·3	...
Barrackpore	284	320·4	...
Benares	147	122·4	6·8
Allahabad	978	127·7	...
Lucknow	2,369	103·4	...
Cawnpore	986	50·7	...
Bareilly	1,050	100	...
Meerut	1,842	260	...
Delhi	298	359·1	...
Ambala	2,365	113·3	...
Jullundur	619	101·8	...
Ferozepore	887	324·7	1·05
Amritsar	162	259·3	...
Lahore Cantt.	890	137·1	...
Fort Lahore	112	125	...
Sialkote	1,294	216·4	...
Rawalpindi	2,724	268·7	...
Nowshera	592	631·8	...
Peshawar	1,402	475 0	...
Multan	869	138·1	0·58
Hyderabad (Sind)	492	609·8	...
Karachi	1,267	275·5	...
N.-W. Frontier, Indus Valley and N.-W. Rajputana.	4,621	391·5	0·58
Nasirabad	781	510·9	...
Agra	999	181·2	0·49
Jhansi	958	366·7	1·68
Mhow	1,752	173·5	0·31
S. E. Rajputana, Central India, Gujrat ...	5,730	241·7	1·15
Saugor	304	286·2	0·60
Jubbulpore	976	161·9	3·27
Kampti	932	149·1	3·10
Secunderabad	3,154	26·6	6·12
Belgaum	1,055	70·1	0·12
Poona	1,901	140·5	1·68
Ahmednagar	1.061	33·9	2·49
Deccan	10.260	89·8	17·34
Colaba, Bombay City	1,656	227·3	9·88
Madras	555	70 8	...
Bangalore	2,197	27·8	...
Western Coast	1,372	188 8	0·4
Southern India	3,537	42 1	0·2

* Includes benign tertian and quartan fevers.

† Includes malignant tertian fever.

Incidence of malarial fevers in Native Troops in 1891—00, 1906 and 1907, according to the twelve geographical regions of the Indian Empire.—The following table gives the geographical distribution of malaria in Native Troops in the 12 regions of the Indian Empire :—

Geographical regions.	Years.	Average strength	Admissions for all causes per 1,000.	RATES PER 1,000 OF STRENGTH. *Admissions from* Intermittent fever.*	RATES PER 1,000 OF STRENGTH. *Admissions from* Remittent fever.†
Burma Coast and Islands in Bay of Bengal.	1891-00	1,891	194	195·2	6·6
	1906	1,349	485	108·2	0·7
	1907	1,297	563	154·2	11·6
Burma Inland	1891-00	6,083	1,165	576·6	10·2
	1906	2,836	674	222·5	1·1
	1907	2,807	629	161·0	2·1
Assam	1891-00	2,003	1,209	512·1	16·5
	1906	954	775	502·9	2·1
	1907	964	1 059	407·7	21 8
Bengal and Orissa	1891-00	2,935	1,120	511·2	15·0
	1906	1,816	876	303·4	6·1
	1907	2,022	907	429·3	21·8
Gangetic Plain and Chota Nagpur	1891-00	6,463	668	215·4	12 5
	1906	6,209	504	140 9	3·4
	1907	5,590	441	97·3	3·3
Upper Sub-Himalaya	1891-00	15,166	732	280·8	17·9
	1906	20,842	600	227·7	4·8
	1907	20,904	582	218·7	4·8
North-West Frontier, Indus Valley, N.-W. Rajputana.	1891-00	15,459	1,102	507·5	22·2
	1906	19,224	938	468·3	7·3
	1907	18,024	951	433·3	7 7
South-Eastern Rajputana, Central India and Gujrat.	1891-00	12,679	814	337·5	11·3
	1906	13 243	767	355·3	3 9
	1907	13,094	636	253·1	2·6
Deccan	1891-00	19,504	736	292·6	11·2
	1906	16,591	579	110 0	3·3
	1907	16,794	492	78·1	1·1
Western Coast	1891-00	3,055	714	159·9	14 9
	1906	1,783	804	260·8	1·1
	1907	1 632	930	249·4	0·6
Southern India	1891-00	8.244	565	132·0	3·6
	1906	4,282	605	166 0	1·6
	1907	3,880	415	57·7	1 0
Hill Stations	1891-00	17,027	1,075	470·0	24·6
	1906	22 403	735	250·0	6·5
	1907	22,700	634	217·8	5·9
Army of India	1891-00	127,666	832	348·8	15·2
	1906	127,853	684	261·8	5·0
	1907	126,392	629	220·5	4·5

* Includes benign tertian and quartan fevers.
† Includes malignant tertian fever.

Malaria in Jails.—Monthly incidence of Malarial Fevers in Prisoners in Jails in India.

Form of fever.	Years.	January.	February.	March	April	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Remarks.
Intermittent* ...	1903	1,220	1,085	1,584	2.124	1,787	1,439	1,566	1,759	2,231	3,412	2,578	1,830	22,605	Intermittent fever includes all cases of benign tertian and quartan fever; Remittent all cases of subtertian. The average strength of the jail population during the periods 1903—07, was approximately from 107,000 to 110,000.
	1904	1,253	1,089	1,154	1,329	1,393	1,293	1,411	1,999	2,553	2,565	2,025	1,461	19,525	
	1905	1,083	974	1,123	1,292	1,365	1,264	1,319	1,551	1,843	1,877	1,725	1,297	16,704	
	1906	865	637	900	1,163	1,177	1,237	1,685	1,906	2,502	2,893	2,846	1,917	19,765	
	1907	1,471	959	1,055	1,173	1,362	1,265	1,434	1,593	2,038	2,139	1,859	1,393	17,741	
Remittent† ...	1903	15	2	14	12	21	24	15	11	4	13	17	5	143	
	1904	4	10	6	13	10	8	14	13	5	10	6	3	102	
	1905	4	3	5	10	13	16	8	4	15	10	10	11	109	
	1906	9	3	9	6	10	16	10	9	9	22	26	11	140	
	1907	10	4	8	8	10	8	13	16	3	6	6	8	100	

* Includes benign tertian and quartan fevers.
† Includes malignant tertian fevers

Monthly incidence of different types of malarial fever in Calcutta Bombay, etc.—The following comprehensive and interesting tables give the monthly incidence of the varieties of malarial fever of this country as seen in Calcutta, Eastern Bengal and Bombay. In Bombay the incidence corresponds fairly closely with that of Calcutta. The chief difference is the larger number of cases in the first half of the year, especially in the case of sub-tertian infections. This is explained by Major LEONARD ROGERS, I.M.S.,* as due to there being a more uniform temperature in Bombay; no part of the year is sufficiently cold to cause an entire cessation of new infections. In Calcutta ROGERS has shown that in December there is a rapid decline of sub-tertian, coincidentally with a fall in the minimum air temperature to 60° F. or below.

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*_Fevers in the Tropics_, p. 199.

*Monthly Incidence of different forms of Malarial Fever in India.**

		January.	February.	March.	1st Quarter.	April.	May.	June.	2nd Quarter.	July.	August.	September.	3rd Quarter.	October.	November.	December.	4th Quarter.	Total.	Percentage.
Calcutta two years' cases in Europeans.	Quartan	...	...	1	1	...	...	1	1	1	...	...	1	1	...	1	2	5	2·5
	Benign Tertian ...	5	5	4	14	5	6	7	18	9	10	10	29	11	17	7	35	96	48·0
	Malignant Tertian ...	4	...	...	4	1	1	1	3	8	7	8	23	18	31	21	70	99	49·5
	Total ...	9	5	5	19	6	7	9	22	18	17	18	53	30	48	29	107	200	...
Megaw's one year's Medical College cases, Calcutta.	Quartan ...	6	6	3	15	1	1	1	3	2	4	...	6	3	4	3	10	34	10
	Benign Tertian ...	9	9	2	20	5	2	4	11	2	11	18	31	14	20	16	50	112	33
	Malignant Tertian ...	16	3	5	24	6	5	4	15	7	13	25	45	44	39	26	109	193	57
	Total ...	31	18	10	59	12	8	9	29	11	28	43	82	61	63	45	169	339	...
Powell's two years' Bombay cases.	Quartan ...	1	1	2	4	3	9	6	18	2	2	2	6	2	...	2	4	32	1·4
	Benign Tertian ...	74	50	69	193	59	72	64	195	132	140	113	385	137	146	108	391	1,164	52·6
	Malignant Tertian ...	77	61	50	188	60	60	72	192	87	82	88	257	130	139	113	382	1,019	46·
	Total ...	152	112	121	385	122	141	142	405	221	224	203	648	269	285	223	777	2.215	...
Dr. Laura Hope's one year's Pubna cases (Eastern Bengal).	Quartan...	123	122	141	386	46	60	85	191	72	64	51	187	49	51	69	169	933	52·2
	Benign Tertian ...	16	9	20	45	49	27	9	85	16	7	9	32	7	25	23	55	217	12·2
	Malignant Tertian ...	72	35	29	136	61	28	16	105	19	28	38	85	62	81	78	221	547	30·6
	Mixed	4	7	14	25	11	8	8	27	5	2	6	13	3	12	7	22	87	4·9
	Total ...	215	173	205	592	167	123	118	408	112	101	104	317	121	169	177	467	1,784	...

* From Rogers, *Fevers of the Tropics*, p. 198.

Much has yet to be done in connection with the differentiation of non-malarial pyrexias of India. The group of fevers "Pyrexia of uncertain origin" having replaced "Simple continued fevers" greater accuracy is expected as far as malarial fever is concerned in the future. It is, however, very important that these fevers of uncertain origin should themselves be worked out. The frank admission of our absence of knowledge regarding the etiological relations of these fevers is a step in the right direction. Whilst our knowledge of Indian fevers is growing yearly, we are still far from the time when accuracy can be looked for. It is in the more exact diagnosis of the large group of cases of simple continued and other obscure fevers, and in more complete inquiries into their epidemiology and pathology that our hopes are fixed.

Result of microscopical examination of malarial blood in India.—In the year 1905-6, of 8,106 cases of malaria among European Troops in India in which the type of fever was diagnosed by *clinical methods*—

73·37	per cent.	were diagnosed as	benign tertian.
1·28	do.	do.	quartan.
5·0	do.	do.	malignant tertian.
0·58	do.	do.	malarial cachexia.
19·56	do.	do.	undifferentiated.

Of 72 stations in which the *microscope* was used for 2,797 cases—

85·2	were recognised	as those	of	benign tertian parasite.
2·5	do.	do.	do.	quartan.
11·7	do.	do.	do.	malignant tertian.

Quartan parasites were found in 17 of the 72 stations; in Port Blair, they were three times as prevalent as benign tertian. Again the proportion of malignant tertian to benign tertian was most marked in Port Blair, Jacobabad, Jubbulpore, Kamptee and Allahabad. In Port Blair and Jacobabad there was more sub-tertian than benign tertian. The statistics show that mixed infection is by no means frequent, for of 2,797 cases diagnosed microscopically, only two cases of mixed sub-tertian and benign tertian were found, and both these cases occurred in Allahabad. "As there were difficulties in differentiating the types of malarial parasite in some cases these figures are only approximate."*

Of 2,415 blood films with positive results examined at the different laboratories in 1907 for malarial plasmodia, there were 78 per cent. benign tertians, 19 per cent. malignant tertians, and 1·2 per cent. quartans.

The following table shows to some extent the relative numbers of the types of malarial fever amongst European Troops in 1908, in the various Divisions of the Army in India. The figures represent the

* *Report on Sanitary Measures in India*, 1905-06, Parliamentary Blue-Book, p 33.

blood examinations conducted in the different Division Laboratories :—

Division.	Malignant tertian.	Benign tertian.	Quartan.	Undifferentiated.	Total.
1st (Peshawar) ...	198	1,302	2	...	1,502
2nd (Rawalpindi) ...	23	42	...	...	65
3rd (Lahore) ...	69	30	1	37*	137
4th (Quetta) ...	20	155	2	...	177
5th (Mhow) ...	381	525	5	...	911
6th (Poona) ...	300	255	7	...	562
7th (Meerut) ...	16	550	4	...	570
8th (Lucknow) ...	1	3	...	...	4
9th (Secunderabad) ...	20	69	2	...	91
Burma	31	151	1	...	183

Prevalence of malarial fevers on field service.—The incidence of malarial fevers in nearly all our Indian campaigns preponderates *facile princeps* over other diseases. A glance at the various medical statistical tables of our Indian campaigns shows that malarial fevers in every instance play the predominating part in giving rise to inefficiency, and this holds good in both our European and Native Troops.

Mortality from malaria in India.—It is difficult to arrive at a correct conclusion as to the mortality from malarial fevers amongst the civil population in India, as 90 per cent. of deaths are said to be due to "fevers." In the large majority of these deaths the village headman makes the diagnosis. When a series of these mortality statistics has been analysed, it will be found that a comparatively small proportion are actually due to malarial fevers. ROGERS analysed 1,000 such deaths in the Dinajpur District in Lower Bengal, and came to the conclusion that about one-third were due to malaria and kala-azar. "Of the deaths clearly due to malaria no less than three-fourths were in children under 15 years of age, and the great majority of them occurred in the four last months of the year." This is the ordinary season of maximum malarial incidence all over India. They formed 15 per cent. of the whole. In a further 18 per cent. there was evidence of cachexia, marked enlargement of spleen and prolonged fever, but it was impossible to say how many were really malarial.

* "Small 'rings' which could not be differentiated with precision."

The mortality from malaria "is a mere trifle compared with the ravage fever commits in sapping the strength and vigour of the people; fever destroys the life of the country—the deaths must be multiplied by 50 or 60 to give the attacks."* The late Sir JOSEPH FAYRER remarked regarding the effects of malaria that "the sun's rays, the heat and other ills, pale into comparative insignificance before its incessant operations against the health and lives of human beings in tropical and tropoidal regions, and of the higher animals essential to the welfare and happiness of man."†

Under suitable treatment malarial fevers are seldom fatal. Even when untreated the death rate is low. In consequence of the enormous numbers of cases in malarial districts, the weakness, anæmia, enlarged spleen and general disability that occur, however, greatly interfere with the economic prosperity and industrial success of the people.

Cost of malarial fevers to the State in India.—It would be interesting to estimate what malaria costs the State per annum in the various provinces and in the Army in India, were it not that the undertaking would be largely theoretical. Such an estimate would include the original cost of all anti-malarial operations, of hospital accommodation for malarial cases, cost of medical service, feeding, nursing, invaliding, and cost of training recruits to replace mortality and invaliding (direct and indirect) from malaria. Apart from these items are—the constant reduction of the effective strength for active service, the great prevalence of malarial fever cases in Indian campaigns, cost of transferring these cases to the base, and of getting others up to the fighting line to take their place.

CONTRIBUTORY CAUSES OF MALARIA.

While the direct cause of malaria in man is an infection of the red cells by species of protozoal organisms, which infection is transmitted through certain species of anophelines, there are certain contributory factors in connection with the etiological relations of malaria which it is convenient to consider before dealing with the parasites of malaria and the mosquito-malaria hypothesis.

These *contributory factors* are—meteorological relations and telluric conditions favourable to malaria, the influences of marshes and other large collections of water, and the personal predisposing causes of malarial infection.

These are causes which enter indirectly into the etiology of malarial infections. They favour the development of the parasite in the body, or indirectly assist in infection through mosquitoes.

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* FLORENCE NIGHTINGALE, *Life and Death in India.*

† *Climate and Fevers of India.*

In later Sections it is proposed to consider the mosquito-malaria hypothesis, the bionomics of mosquitoes, the *direct cause of malarial fevers,* the various species of malarial hæmosporidia, and the methods of measuring the endemicity of malaria in India.

CONTRIBUTORY EPIDEMIOLOGICAL FACTORS IN MALARIA.

A.—Metereological Relations of Malaria.

Temperature.—This has an important bearing on malaria. A temperature of 15° to 16° C. (59 to 62° F.) is the limit at which malarial fevers occur. Those regions in which this temperature is not attained by the mean summer temperature remain exempt from malarial fevers.

A certain degree of atmospheric heat is required for the development of the malarial parasites in the mosquito. From this it follows that anophelines may be harmless at a low temperature, but dangerous when the temperature rises.

In endemic malarious areas during the winter, mosquitoes are driven into houses, huts, stables, and then the malarial parasites in a large number of them perish. In the spring again in many parts of India the mosquitoes become re-infected from cases of relapses. These relapses or residual cases form the means by which malarial fevers are maintained between the malarial season of one year and the year following.

It has been demonstrated that both a low and a high atmospheric temperature are unfavourable to the development of the malarial parasite in the mosquito, the most favourable temperature being between 24 and 30° cent. (75 and 86° Fahr.), although a sudden change to a low temperature from a favourable one does not interfere with the development of the parasite in a mosquito that has been already infected. It is said to be probable that some anophelines in cold weather may, if once infected, remain so for months. The same would hold good for those infected during the spring who in summer would remain infected while æstivating.

Great falls of temperature in malarious places are important in respect of their being associated with relapses from chills, the latter operating by lowering the physiological resistance and then permitting latent malarial pararsites to multiply.

Moisture.—This is a significant factor in connection with the occurrence of malaria. The typical malarious locality is low and marshy, or in the vicinity of rivers, lakes, and large accumulations of water. Some regions in India, almost free from malaria in the hottest part of the dry season, become very malarious shortly after the commencement of the rains, and their malarial intensity becomes greater during the autumn. Moisture is essential for the development of the eggs and larvæ of anophelines.

The great importance of humidity of the soil is shown by the association of malaria with marshes, jheels, swamps, and the banks and drying beds of rivers and the sea coast. The period following the overflowing of rivers and inundation of the surrounding country is specially malarious. This latter condition is imitated artificially over large tracts in this country by the irrigation of rice, and to a limited extent sugar-cane fields.

Small swamps, and the collections of water seen round or near villages, are responsible for much of the malaria met with in rural districts.

Rainfall.—The amount of rainfall, and the period over which the rainy season continues, have an important influence on the prevalence and distribution of malaria in India. Rainfall conduces to the production of malaria because it is favourable to the development of larvæ of anophelines. Heavy torrential rains have the effect of washing away mosquito larvæ, whilst intervals of dry weather dry up the pools and may be associated with dessication of larvæ. The most favourable conditions for mosquitoes are intermittent and moderate rainfall with intervals of sunshine, if there is sufficient water collected for oviposition, and time enough for hatching the eggs out. Alternate saturation and dessication of the soil is especially favonrable to the extension of malaria, just as a permanently permeated wet, or a completely dry soil. is unfavourable to malaria. The banks of the Jumna, Ganges, Indus, and Brahmaputra and other Indian rivers periodically overflow their banks, and malaria appears in the tracts affected shortly after the subsidence of the overflow. This leads us to infer what actually is the case—that mosquitoes flourish in the shallow pools and puddles left in the beds of the rivers after this subsidence, and do not thrive in great collections of rapidly flowing water where they would be washed away in the torrents and eaten by fish. When the pools left are flooded, washed out and converted into deeper collections of water, the evolution of mosquitoes from ova to imago is greatly interfered with. During a dry period following rapidly upon heavy rains or freshets, malaria outbreaks are severe and frequent. This phenomenon is constant and pronounced all over India.

Wet years in Northern India, and especially in the Punjab, considerably increase the incidence of malarial fevers. There are many stations, however, in which, even in dry years, these fevers are very prevalent, such as Peshawar, Mardan, etc., the explanation being that the anopheline population is maintained by the large number of irrigation channels in use and by rivers.

In general terms it may be stated that malarial fevers are most prevalent in India during the years of the heaviest monsoon rains—these are the years in which we get epidemic and pandemic outbursts—and this is particularly the case in the level plains, and localities in which the drainage is slow or in any way obstructed.

Winds.—This diffusion of malaria by winds occurs only over very limited distances, as hills, trees, and other obstacles may protect houses to leeward of breeding places of anophelines. This is explained by the known habits of anophelines who are weak fliers, and in winds secrete themselves in trees, brushwood and bushes, and even in grass ; mosquitoes are easily hindered in their flight by obstacles.

Ships anchoring at short distances from malarious places are not attacked by malarial fevers or invaded by anophelines. If the germs of malaria were carried through the air it would not be possible to explain why they do not affect people at a reasonably short distance from their origin or breeding place—(see *Air Theory of Malarial Infection*, p. 36).

Climatic and seasonal relations of malaria.—The climate and season of the year are important factors both in the incidence of malaria and development of anophelines. Malarial fevers are prevalent when the conditions of heat and moisture favourable to the development and activity of anophelines are in existence. In temperate climates malarial fevers occur only during the warmest season of the year. In the tropics, whilst these fevers prevail for much longer periods each year, their incidence is highest during the rainy season and the period following it. Most cases occurring at the first half of the year are considered to be relapses and not cases of initial infection.

Climate has a distinct influence as regards the distribution of certain types of malarial infection in India. The factor of heat is universally present and does not appear to affect the question of intensity so much as would be expected, except that in certain parts of India, especially in Southern India and along the sea border, it permits of anophelines breeding all the year round. Temperature as far as India is concerned can only be looked on as a predisposing cause affecting the breeding of anophelines, the development of malarial parasites in anophelines, and the multiplication of malarial parasites in the blood of man.

Season has a marked influence as regards the number of cases met with in any locality. This is to a large extent affected by the prevalence or fewness of anophelines, although this is not the entire explanation, especially in localities where there are few malaria-bearing anophelines with severe malaria in man. In this country so well marked is the effect of one particular part of the year on the prevalence of malaria that we call that period the *malarial season*. This usually occupies about four months and these months are different in different localities. They are generally August to November, but they may be much earlier as in Burma. The commencement of our great Indian epidemics and pandemics of malaria usually occurs during the latter part of summer and in autumn.

There are in endemic centres periods of maximum and minimum incidence—the maximum is usually the autumn, and the minimum the spring and early summer months. The maximum prevalence is therefore towards the end of and shortly after the rainy season.

In many parts of Northern India a heavy fall of rain in March, April, or May, is connected with an increased incidence of malaria a month or six weeks after this fall, leading some medical officers to consider that this accession of cases has been due to relapses arising from chills caused by reduced atmospheric temperature. Were this the case, however, the increased incidence would occur immediately or shortly after the fall. It is much more probable that it is due to malaria-bearing anophelines taking advantage of the presence of water to lay eggs in, and that these additional malaria cases are due to infection through the new generation of anophelines. Whether such is the case or not could easily be decided by observations made at these rainfall periods in late spring and early summer.

Accepting the fact that mosquitoes are the only carriers of malaria from man to man, malarial fevers must necessarily be seasonal, the maximum period of incidence of these fevers closely corresponding with the time mosquitoes are most numerous. There may appear to be a contradiction to this statement in malarial fevers occurring during periods when mosquitoes are practically absent. This is readily explained by the occurrence of relapses of such fevers in untreated or badly treated cases.

B.—Geological and other Relations of Malaria.

Telluric relations of malaria.—In connection with malaria the degree of porosity of the soil is of great importance, whereas the actual geological constitution and proportion of animal and vegetable constituents are of no significance. A soil that permits of its contained water to drain rapidly, or that quickly absorbs such water, is unfavourable to malaria ; one that holds up its surface water in small collections, such as small lakes and pools, etc., and only gets rid of it slowly, fosters malaria. Hence rocky soils (except where full of holes and shallows which retain water) and deep sandy soils, are not favourable to malaria ; but a granite soil covered by a layer of clay or even porous earth may be associated with severe malarial fevers.

Loose, porous, sandy, alluvial and argillaceous soils, deep loamy marshy lands, with a substratum of clay affording capacity for the retention of water, and level countries presenting physical obstacles to underground drainage, are most favourable during a moderately high range of temperature, to the development of malaria.

Many alluvial soils, especially those most recently formed, are malarious, although they may not be marshy. Many alluvial soils have a flat surface, a bad outfall, and are in the vicinity of streams which may cause great variations in the level of the ground-water. Uneven mud banks also, on the side of rivers and large streams, especially if only occasionally covered with water, may be highly malarious ; this is the case with many rivers and with deltas and old estuaries. Vast tracts of ground in Bengal, and in other parts of India, along the course of the great rivers (Ganges, Brahmaputra, Indus, Nerbudda, Kristna, etc.) are made up of soils of this description, and some of the most important towns and stations of India are placed on such sites. The deltas of great rivers present these alluvial characters in the highest degree, and should never be chosen as sites for building on. If they must be used only the most thorough deep drainage can make them healthy.

Impervious soils impenetrable to water, and which permit of the formation of pools and collections of stagnant water, are the most dangerous. Marshes and swamps, where the surface of the soil is partially covered with water, are very favourable to anophelines. Adequate and scientific drainage and the formation of canals in such areas are followed not only by reduction of malaria, but by the improvement of the general health.

Vegetation, *per se*, has nothing to do with malaria—malaria may abound in its most concentrated and deadly form where little or no vegetation exists.

The most putrid animal decomposition with an abundant evolution of ammonia and sulphuretted hydrogen is not associated with the production of malaria.

There is no scientific evidence to indicate that malaria is in any way related to the mineral constituents of the soil. It is found to exist in all kinds of soil—alluvial, sandy, or ferruginous earths, and even on soils arising from the weathering of metamorphic rocks. The one essential and constant relation of soil to malaria is the presence of facilities in the soil for the collection of surface water wherein mosquitoes can breed. Hence we find that low-lying lands covered with rank vegetation and marshes, such as river estuaries, are frequently endemic malarial localities. In such cases the complete drainage of the soil, or the flooding of the surface, at least partially, and sometimes entirely, renders them non-malarial. It was formerly thought that malaria was produced by excavating or upturning the soil in endemic malarial areas—that malaria was due to a poison or miasm which was contained in certain soils, and that when such soils are dug up or turned, the poison makes its exit. This is the basis of what was known as the *telluric origin of malaria*. The records of the history of malaria are full of instances of malaria said to have arisen in this way. We now know that in a large number of these instances the cases were either not malaria at all, or were merely relapses of malarial fever occurring in those employed in such work—cases in persons who had previously suffered from malarial fever—whilst others were probably cases of initial malarial infection acquired in the usual way by the bites of infected anophelines at some antecedent date. That these explanations are the correct interpretation of such cases in India is only too well known from the large number of coolies infected in road-making, in making railway embankments, excavating canals, in all of which occupations often thousands of persons are housed together in temporary thatched huts adjacent to the works surrounded by marshes, or by collections of water contained in borrow-pits which they have made during the course of the work, in which excavations myriads of anophelines breed.

All experiments made to infect man with soil, air, or water from malarial marshes have failed. Such experiments have been frequently made.

Subsoil water level in relation to malaria.—As a general rule it may be said that a persistently low ground water level, say 15 to 20 feet, is unfavourable to malaria, that a persistently high level, say 3 to 5 feet, fosters malaria, and that a level which fluctuates is liable to be most malarious. This opinion is forced upon us from the general literature of the subject and experience of malaria throughout this country. The author's personal experience extending over 24 years, during 10 of which he has been Health Officer in a locality where malarial fevers are endemic, is that there is an intimate relation between the height of the subsoil water and malaria.

The relation of the height of the subsoil water to malaria is shown from the following table from a report published when one was Health Officer of a large Deccan Municipality :—

Table of causes of Malarial Fevers treated in the Civil Dispensary of Chudderghaut during the years 1887—1889.

Year.	Number.	Remarks.
1887 ...	37,000	High subsoil water level.
1888 ...	28,136	High but oscillating subsoil water level.
1889 ...	7,618	Uniform but low subsoil water level.

The vast number of people that were affected with malarial diseases in the year 1886 led to inquiries regarding the causes of this malaria. The opinion arrived at was that it was due to the high subsoil water level, together with excessive "wet" cultivation within municipal limits. In the year 1889 wet cultivation was prohibited over an extensive area. The great disparity between the number of cases of malarial fevers occurring in this year and 1887 (7,618 and 37,000 respectively) is probably attributable to the uniformly low level of the subsoil water in 1889 and its high level in the year 1887.

"In the Dinajpur district I found a close relationship between high ground water levels throughout the year and both high spleen and malaria death rates, while low ground water levels were accompanied by much less prevalence of malaria. The great improvement in health in Algeria, following a lowering of the ground water level by drainage, shows the great value of this measure, which is about to be tried in some very malarial parts of Jessore (Lower Bengal)." *

Configuration of the ground.—This is highly important as it affects the manner in which surface water is disposed of. Hollows, ditches and all excavations without outlets, given other conditions, favour malaria; *per contra*, elevated sites, if they permit of rapid drainage, are unfavourable.

It has for centuries been held that the "virus" of malaria does not ascend much above the level of the ground. In the medical literature of India of the last century one frequently comes across the phrase "malaria loves the ground." This is now explained by the fact that anophelines are not high fliers and will keep close to the ground when food (in the form of human blood) is there available.

Altitude as affecting malaria.—Whilst malaria is seldom met with at great altitudes, the old hard and fast rule that malaria did not occur by initial infection beyond 4,000 feet in India is certainly incorrect. One has proved the co-existence of malaria-bearing anophelines and malignant and simple tertian fevers at 4,300 feet (Bakloh), and of infected mosquitoes and the same varieties of malarial fever at 6,000 feet (Kohima, Naga Hills, Assam). It is known to occur at 8,000 in Mexico. The general statement holds good, however, that the higher we ascend the less the chances of a place being malarious, because the physical, telluric and climatic conditions become more unfavourable to the development of mosquitoes. Given suitable conditions, mosquitoes can thrive at high levels. "Nevertheless the reported existence of malaria in localities which from general geographical conditions might be expected to be free from the disease should always be carefully investigated, for relapses may occur in any climate and under a great variety of conditions" (THAYER). On the other hand one has recently, during the malarious season of the plains, investigated the malaria of seven hill stations ranging from 5,000 to 7,400 feet high (Almora, Ranikhet, Chaubattia, Lansdowne, Landour, Kailana and Chakrata); in six of these both anophelines and initial malaria were absent; in Almora (5,000 feet) a few *Nys. maculatus* and an unidentified species of Nyssorhynchus were found, and it was very doubtful if any cases of initial malaria occurred in the station.

The limit of malaria given by HIRSCH in India and Ceylon, *viz.*, 2,000 metres is very near the truth, as the records show but few instances in which fresh infections of malaria occur beyond 6,500 feet. Malarial fevers are usually most severe and persistent in low-lying coast districts; deltas of large rivers in India are especially liable to outbursts of epidemic malaria. This is true of all bodies of water situated in

* ROGERS, *Fevers of the Tropics*, p. 203.

low-lying places. These are the places in which we get (1) a dense population, (2) a large floating population many of whom are susceptible to malaria, and (3) swarms of malaria-bearing anophelines. Hence we find malarial fevers in India very prevalent in the low lands in the neighbourhood of the large rivers such as the Ganges, Indus, Godavery, Krishna, in Assam along the Brahmaputra, in which province it is also very virulent on the lower slopes of the hills and in the valleys along the branches of the Brahmaputra; in Burma it is specially malignant along the valleys of the Irrawaddy, Chindwin and Moo—some of the worst malignant infections one has seen were in our troops returning from expeditions along these rivers in the war of 1886-87; in Manipur (about 3,000 feet), which is a small territory thirty miles long by ten wide, surrounded by low hills and intersected in every direction by streamlets and irrigation canals, malaria is exceedingly prevalent. Along these rivers there are unlimited breeding grounds for anophelines.

C.—Relation of Marshes and Places Simulating Marshes to Malaria.

In the epidemiological relations of malaria, one of the oldest beliefs and most substantial facts we possess is that marshes have an intimate relation with malaria; its earliest name, "marsh poison," indicates this.

Marshes, swamps, jheels, etc.—In India the inhabited regions adjacent to swamps, marshes, jheels, lakes, ponds, and other places simulating marshes, are practically always malarious; some of the worst foci of malaria in the Indian Empire, such as Assam, the Himalayan Terai, Bhutan Frontier, Manipur, the valleys of large rivers (Ganges, Indus, Jumna, etc.) are found near these collections of water.

Nevertheless there are swampy regions of vast area where no malaria is met with, indicating that other factors are necessary for the generation of malarial fevers; *per contra*, there are regions perfectly free from marshes and swamps which are endemic seats of malaria. In vast tracts of the Punjab there is an absence of marshes and swamps, the soil is dry for a large part of the year (the water being in many districts from 50 to 100 feet below the surface), yet there are various other sources of water such as the streams of the five great rivers, and the extensive areas supplied by irrigation. The same may be said of the highlands of Persia. The Upper Godavery province is the most malarious in the Deccan, yet in it there is not an acre of marshy ground. It is now well established that a marsh or swamp is not needful for the development of malarial diseases.

In India marshes, swamps, ditches, and the low grounds subject to overflow by rivers, afford that conjunction of telluric conditions that is most favourable to malaria.

A marsh at some distance and in evidence is often incriminated when the real cause of malaria is in the immediate vicinity of unhealthy houses, and frequently a close examination will prove the existence of many undiscovered or unexpected nurseries of anopheline larvæ.

A plateau above a marsh is dangerous. Even the slope of a hill a situation ordinarily to be recommended as a building site, when above a *jheel* or swamp, is likewise to be avoided, except when the wind is constant in the direction opposed to the slope, or from the slope to the *jheel*.

Tanks.—These form one of the largest classes of breeding places of anophelines in this country. They are found around and in every town, station, cantonment, village and hamlet. A large number of tanks fill, during the south-west monsoons, but after the rains, begin to dry up and become sources of malaria. From this we may infer that whilst an ordinary or temporary camp may be formed near a tank full of water, a permanent camp should never be so located. The same applies to marshes, banks or beds of rivers which are drying up; all such places should be avoided for camps and as building sites.

Ravines.—In India ravines are always unhealthy, especially if covered with jungle, close brushwood, etc. The mouths of ravines are specially dangerous places. The summits of ravines are at times also malarious, especially if only a few hundred feet high.

Irrigation canals.—As a source of anophelines these are very important in India. Some anophelines breed almost exclusively in running water and for these irrigation channels are favourite nurseries. Irrigation channels not only breed mosquitoes but the soil around becomes sodden and collections of water form along the irrigated area.

Irrigated lands.—These are another source of malaria, particularly when they are neglected. Irrigation canals supply vast tracts of cultivated land in India. In Manipur, all the jheels and rice-fields are connected by canals, and in these anophelines are found to breed in myriads.

Malaria is more persistent in its prevalence, more virulent, and therefore more fatal in its results, in the canal irrigated tracts than in the country not irrigated by the canals, unless this should be naturally a very moist district. "Indeed, nothing can be more marked as a rule than the difference in the aspect of the people who live where the well-water is found at more than 30 feet from the surface, and where it is found at less than 15 feet." "For eight months of the year, when all the country is dry, away from the canal-irrigated or moist terai countries, it is unusual to find a case of ague in any village; for four months of the year, when all the land and air is moist, it is difficult to find any village in which persons are not suffering from ague, and this suffering is more general, more lasting and fatal, as the rainfall of any year is greater or late, so that its drying up is delayed." *

Ditches.—Next to irrigation canals, in the production of malaria, may be enumerated *ditches* surrounding towns, cities and forts, and the badly graded ditches in flat districts generally. There can be no doubt that the ditches surrounding towns, either when they become stagnant, or when they are drying up by continued heat, become the source of malaria in the same way that marshes are; they are often the cause of disease to the inhabitants for whose protection they were made. Ditches of whatever description, whether used for the protection of towns or of camps, or for draining the soil, unless carefully looked after are in India productive of malaria, particularly when they are drying up.

Pools, ponds, etc.—The influence of *pools* in the production of malaria must be evident from what has been already advanced.

One of the great causes of the increase of malarial fevers in certain districts appears to be the more universal construction of roads, railways, irrigation tanks, and irrigation canals, which obstruct the outfalls of the subsoil water in the one case, and keep the soil damp and water-logged, and in many districts marshy, in the other.

Rice cultivation.—Until a few years ago authorities were not agreed as to whether rice cultivation is unhealthy or innocuous. A rice-field under irrigation might be regarded as a type of swamp or marsh. The varying physical states of the soil in *paddy-fields* is precisely such as we should expect to find associated with a prevalence of malarial fevers; they have the characters of marshes—alternately saturated with water and drying-up It is an important point therefore to decide the distance paddy fields should be from inhabited places, towns, barracks, etc. Amongst medical officers in India opinion is in favour of making this distance as great as possible. Personally one considers that rice cultivation should not be permitted within a mile of towns and cantonments in India. In Italy, it is not allowed within five miles of towns.

Rice cultivation is undoubtedly inimical to health under certain circumstances. In India, without adequate subsoil drainage, it is undoubtedly injurious to the health of the cultivators, and will continue to be so under existing agricultural methods.

The healthiness or unhealthiness of a rice-field to some extent depends on the amount of water available for irrigation. Revenue Officers in India used to classify these fields as "one crop," "two crop"

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* F. N. Macnamara, *Himalayan India*. Report on Malaria in the North-West Province and Oudh, 1866.

or even "three crop" fields. It might perhaps be safe to say that "one crop" cultivation is almost certain to cause malaria in the vicinity; that "two crop" cultivation is less dangerous, and that, other causes being absent, there is much less malaria in the vicinity of "three crop" cultivation.

It has been ascertained that the rice grounds in some parts, such as Trichinopoly, Tanjore, and other places in Southern India, where the plantations are almost constantly inundated,* are less fertile in the production of malaria than those which after inundations are exposed to the action of a powerful sun. This consideration will assist in explaining the varying degrees of unhealthiness in the neighbourhood of the rice grounds in different parts of India.

As stated above the varying conditions found on the paddy-fields of this country are essentially those of marshes, which have been long notorious for malaria production. Hence, if a site in a malarious locality must be selected for habitations in the neighbourhood of wet cultivation, it is essential that surface drainage should be carefully attended to, so that the "tail" of water beyond that requisite for plant life shall be correctly disposed of.

As now carried out wet cultivation is responsible for an enormous amount of malaria in this country, and in Burma, Manipur, and Assam. It is possible by legislation to prevent such cultivation within a certain limit of densely inhabited towns, cantonments and civil stations as is done in Italy, but under the general conditions of agricultural life in India, it is not possible to adopt this measure in rural malarial districts, as the small collections of huts called villages, are in most districts scattered in the very heart of the rice-fields themselves. In endemic malarious districts it is theoretically justifiable to condemn rice cultivation, but in this country where millions depend on rice crops for their existence, this rigid attitude towards rice production cannot be adopted. It is often, in severely endemic malarial districts, a question of allowing the lower classes to die of famine or die of malarial disease, and the former is the worse of the two evils.

The parasites of malaria have never been discovered in the air, water or soil of marshes or places simulating marshes. The connection of marshes with malaria is now explained through the anophelines which breed in them and which find their way from the marshes to inhabited houses in the vicinity.

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* Because owing to an abundance of water they are able to raise three crops in the year. In rice cultivation under tanks the cultivation lasts from October to April, only two crops are raised, and the land lies fallow during the hottest months. In the districts named cultivation goes on for nearly the whole year without intermission, and the ground is always saturated with water.

D.—Personal Predisposing Causes.

Age.—Malaria attacks all ages but most frequently children under ten years. The very old and very young (infants under three months) are less frequently affected with malaria in endemic districts. The former have probably acquired a certain degree of immunity to the parasite, the latter have not had time to get thoroughly saturated with parasites. While adult natives in an endemic malarious locality may be comparatively free from malarial infection, a large percentage of the young children suffer to a greater or less extent, though always to a less extent than new arrivals from non-malarious places.

Sex.—The male sex is attacked more than the female on account of greater exposure to attacks of anophelines. Sex itself, however, has little to do with the incidence of malaria; when both sexes are equally exposed to infection they are equally infected. It is possible to show that where women are largely employed in manual labour like men, they are largely infected. In one instance on a large canal work (the Bari Doab in connection with the Ravi and Beas rivers), where about 2,800 women were employed, one investigated the local malaria and found 910 with malarial parasites in their blood, or 32·5 per cent., and of 1,700 men on the same work at the same time, there were 551 harbouring parasites or about 32·41 per cent. Manipur, which is about 3,000 feet above sea-level, consists of a valley 30 × 10 miles, irrigated throughout by intersecting canals; it is highly malarious; the children are practically all infected with malaria, whilst the men and women, who are throughout equally exposed, are affected to only a comparatively small but equal extent.

Race.—Native adults resident in malarious places are less liable to malarial infection than Europeans. They acquire more or less immunity early in life. The blood of a large percentage of native children is inhabited by the hæmosporidia of malaria. Newly arrived Europeans in malarious localities in India are specially liable to malarial infection. If exposed to malarial influences for some time without suffering from malarial fever, they may acquire a certain small degree of immunity. Under no circumstance does the European in malarious places acquire complete immunity or undergo complete acclimatisation. Maurel states, regarding the white people of French Guiana, that he could not trace a single white family back more than four generations, and definitely declares that no immunity is acquired by the Caucasian race. Eurasians are more subject to malaria in endemic malarial areas than natives, in this susceptibility following their European progenitors. This observation was originally made by Ronald Martin and has been repeated by many experienced medical officers in India.

Apart from constitutional peculiarities, individual predisposition to malarial infection is met with, which may be in part explained by the fact that some people are more attractive to mosquitoes than others.

New-comers in malarial places, especially Europeans, are specially favoured by the attentions of mosquitoes.

Immunity.—It would appear that there is no hereditary immunity, or absolute acquired immunity against malarial infection. The parasite may remain in the system for long periods; latent parasites are of frequent occurrence in adults of endemic districts, it is possible that the parasite of malaria is capable of producing immune bodies in the system for self-defence, and that for this reason the blood plasma and white blood cells are helpless to deal with them. In quinine, we possess a drug which gives us a relative immunity similar to that which the native in malarious places acquires. It is preferable to this natural partial immunity, because in the latter the person harbouring malarial parasites (latent infection) may remain a source of infection long after convalescence.

It is stated that dark-skinned races, living in malarious regions, possess a relative immunity to malarial infection. The explanation is that it is due to an acquired immunity, the result of frequent infections in childhood. In the West Coast the negroes undoubtedly possess a high degree of immunity to malaria. The apparent relative immunity of adults of the West Coast, and of Central Africa generally, may possibly be also due to their thick skin rendering them less susceptible to the bites of mosquitoes, just as, conversely, the thin skin of young children renders them more susceptible.

Acquired immunity.—The relative immunity of inhabitants of endemic areas is acquired and not inherited. We find in such areas a high percentage of the children harbouring malarial parasites in their blood and, in ordinary years, comparatively few adults with parasites. Prolonged residence in malarial districts gives rise in those who survive malarial infections, to a degree of relative immunity. There is no doubt that recurring attacks ultimately render the individual less prone to infection. The explanation may be that the malarial toxins bring about some changes in the human economy which render it less liable to further attacks. In other words, we get a condition in which after repeated attacks of malarial fever which have been less and less severe, there is established a spontaneous and more or less permanent cure. This is brought about more rapidly in some cases where quinine has not been used (Koch). This immunity may endure for years, but any condition lowering the vitality or lessening the resisting power is liable to remove it. The same often arises by going to a new locality.

In all probability the explanation as to acquired immunity is a much more complex and obscure problem than the above statement would appear to indicate, and the factor or factors entering into its occurrence are as yet but imperfectly understood and call for investigation.

Pregnancy and malarial infection.—Pregnant women acquire malaria as freely as the non-pregnant. The later the infection occur during pregnancy, the greater the liability to miscarriage.

Pregnant women can take quinine, but it should be given to them with care and in much smaller doses than in ordinary cases. Where parasites are found it should always be given, and when the symptoms are severe full doses may be necessary. Large doses should never be given to commence with, and the pregnant women should remain in bed while taking it. In some cases the first paroxysm of malarial fever comes on during parturition and relapses are not uncommon at that time in malarious places.

Occupation.—This is a factor predisposing to malarial infection only in so far as it exposes to the attacks of infected anophelines. Those employed in excavating soil in malarious places, in building railway lines, roads, etc., and camping on the sites where these excavations take place, are especially predisposed, because they dwell in the midst of the breeding grounds of anophelines. One of the most formidable instances of severe malaria of modern times illustrating this is the terrible havoc created by malaria amongst the workmen employed during the earlier attempts to make the Panama Canal. This is the more noteworthy when we contrast it with the present practical extinction of malaria effected in the Panama Canal Zone by anti-malarial and anti-mosquito measures. It is probable that people following the above occupations acquire more speedy immunity than those whose occupation keeps them indoors. See Section on *Rôle of Man in the Distribution of Malaria*, p. 31 *et seq.*

State of health.—All conditions enfeebling the body even temporarily, such as common colds, remaining in wet clothes, a wetting in the rain, severe bodily fatigue, excessive mental work, inadequate amount of sleep, excesses of any kind, excitement, defective and insufficient diet, drug habits, parturition, menstruation, minor illnesses of all kinds, injuries acute and chronic, surgical operations and defective dwellings, increase the susceptibility to malarial infection. Hence the advisability of using quinine under all circumstances liable to enfeeble the resistance to malarial infection. Similarly all bodily and mental depressions tend in some way to revive the vitalities of latent malarial parasites and bring about relapses; hence the necessity of completely eradicating malarial parasites once infection has occurred by a prolonged course of quinine.

There is no doubt that persons in good health are capable of throwing off a mild infection of malaria without presenting any clinical manifestations of such infection. This is constantly happening in malarious districts even without quinine prophylaxis.

Impoverishment.—The food of the population is important in maintaining a condition of nutrition that will give the body a certain amount of vital resistance against the multiplication of malarial parasites, when these reach the blood. The question as to the best way of increasing the prosperity of the poorer classes of villagers is one deserving all possible attention. In this connection it is necessary to say that a sufficient quantity of wholesome food can be insured by a minimum wage for all labourers, being enforced on all contractors and other employers of coolie labour. This would of course affect village populations carrying on agricultural work to only a slight extent, but it would affect a very important class of labourers through whom malaria is to some considerable extent disseminated and maintained in this country.

Defective hygiene.—Defective hygienic conditions are important predisposing causes. Houses that are small, damp, dark, ill-ventilated and dirty, are specially favoured by mosquitoes. The small, damp thatch or bamboo huts without windows of most villages are examples. Large houses with lofty rooms, good ventilation, abundance of light and all sanitary needs, considerably reduce the possibility of infection.

The enormous outbreaks of malarial fevers that occur amongst coolies on canal irrigation works are largely fostered by the unwholesome conditions under which they live—huddled together in small *chappar* huts, scantily clothed, with meagre food of small nutritive value, and exposed to night chills. This is a very prevalent combination of conditions amongst large gangs of workmen in this country.

Previous attacks of malaria.—Previous attacks of malaria predispose to further attacks from slight causes. A simple catarrh, indigestion, a hard day's work, a cold bath, and even change to a colder and more salubrious locality, may bring on an attack. Most of such cases are in all probability relapses and not new infections. When any length of time has elapsed since leaving the malarious place, as on the voyage home, after arrival in Europe, or in a non-malarious hill station, etc., and an attack occurs, this is, in the majority of such cases, a relapse. Absolute and permanent freedom from relapses cannot be assured for a year or more of freedom from the last malarial infection. Occasionally relapses are stimulated by "water cures." Men sometimes get their first relapses at Carlsbad after leaving this country—the baths in some way re-invigorating latent malarial parasites.

Time of day.—It is well recognised that the risks of malarial infection are greater during the night, which is now explained by the infection through anophelines usually occurring at that time, as these insects are mainly nocturnal in their attacks on man.

E.—Rôle of Man in the Distribution of Malaria.

Effects of aggregation of large gangs of labourers on engineering works.—In this Section one proposes to deal with the manner in which human agency is to a large extent responsible for the distribution of malaria in India. The rôle of man in the distribution of malaria is one of paramount importance in the epidemiology and prevention of malaria in this country.* The rapid expansion of traffic and facilities for travel by rail have had something to do with this, but the chief factor has been the aggregation of enormous gangs of labourers in the construction of railway embankments, the making of public highways, irrigation canals, expansion of industrial works generally, collections of famine relief labourers, extension of towns, etc. In all such collections there are gathered together a fair proportion of persons suffering from malarial infection, recent or remote. When during the malarial season this infection spreads rapidly, the labourers are rendered *hors de combat*, go to their homes, and are recruited by others who later become victims. We may assume that in all places where such works are instituted anophelines are already in existence. Soon after the opening of such works, conditions are created which give facilities for multiplication of anophelines. In the gathering together of this class, who are usually in a state of physiological poverty and little capable of resisting malarial infection, we combine the conditions that lead to a rapid diffusion and intensification of such infection.

In the production of malarial fevers in man three agencies are necessary—susceptible human beings, certain species of anophelines and malarial parasites. In endemic malarial places these three are as a rule abundantly present during the malarial season, and in general terms it may be said that the intensity of the endemicity varies with the relative numbers of these co-existing agencies. It is easy to quote instances in which there are comparatively few malaria-carrying anophelines with a moderately severe endemicity, *e.g.*, in localities where there is a large number of susceptible persons ; or places where there are numerous malaria-bearing anophelines with a low endemic malarial index, *e.g.*, where there are few susceptible persons.

The great epidemics of malaria in India have been associated with one of many circumstances, such as great overflowing of rivers, heavy rainy seasons, great expansions of irrigation works, famine relief works, unusual activity in railway extension and industrial expansion generally. Except in the first two of these conditions, there is invariably gathered together a large amount of coolie labour. " Labour aggregation with all its attendant conditions appears in this province (Bengal) at least, to supply the key to the riddle of epidemic malaria, in which it seems to have played a part far more important than movement of populations or general scarcity and want." (CHRISTOPHERS and BENTLEY.)

In India all such works as clearing of primæval forests, turning over of virgin soil, earthworks in general, construction of canals, dams, railway embankments, highways, forts, building of harbours, fortifications, barracks, and large industrial works generally—whenever there is

*For a complete and comprehensive review of this aspect of the epidemiology of malaria, see paper by Captain S. R. CHRISTOPHERS, I.M.S., and Dr. BENTLEY read before the Bombay Medical Congress in February 1909.

an aggregation of coolie labour on large engineering or other works, there we see that malaria rapidly disseminates amongst the coolies, during the malarial season.

The more malarious a centre in which works are in progress the more the casualties from death, sickness, return of coolies to their homes, desertion, etc. To keep up the strength new-comers are enrolled who fall victims, and so malarial infection is kept up.

Anyone who has seen a big canal irrigation work, or a railway embankment in process of construction, can comprehend what is meant. Here we have large numbers of people in the depths of poverty and lowered physiological resistance, living in destitution and dirt, working hard, many harbouring malarial parasites, and all exposed to the attacks of infected anophelines. Here we have an accumulation of circumstances which are largely responsible for the intensity attained by malaria wherever the undertaking of large projects in a malarious district involves the employment of numerous labourers and the establishment of labour camps. Under these conditions we are not surprised to find the malarial incidence very high and the virulence of the infection unusually great. This is the condition that is in constant operation in various parts of this country. From these virulently malarial camps malaria is disseminated in all directions when the victims return to their homes. It is from the crowds of these camps that a considerable amount of residual malaria continues to maintain malaria during the non-malarious season, and from them the newly-born anophelines of the monsoons begin diffusing malarial infection wholesale.

The dispersion of these coolies during the continuance of the works from sickness and their final dispersion on the completion of the works, disseminates the malarial germs to other areas where in all probability there are malaria-carrying anophelines. This is going on continuously in this country.

Effects of famine relief works.—*Famines* are specially prone to effect a devastation of the population through malarial diseases, for the impoverished physiological condition of the people permits of malarial parasites producing their worst effects, and this occurs at a time when, as a rule, little can be done to keep malarial infection in check. The large collections of coolies that occur in all famine relief works are fruitful in effecting a dissemination and intensification of malaria by reason of a high degree of susceptibility to infection.

Effects of railway construction.—The construction of railways in India has largely helped to maintain and disseminate malaria, and some districts previously only mildly malarious have been rendered severely so by railway works. This is not exceptional to India, it has had the same effect in all countries where malaria is endemic.

The construction of railways operates in two ways—by the formation of borrow-pits which are favourite breeding places of anophelines, and by the embankments which tend to intercept the flow of subsoil water which would naturally flow into lower lands and find its way to natural water-courses. Rain falling on to the embankment and draining into the borrow-pits helps to keep these latter charged with water. Railways in India were of course started long before we understood how malaria was disseminated by anophelines, but not before we knew that all engineering works interfering with subsoil water drainage gave rise to increased unhealthiness.

One of the most important points in connection with railway construction is the filling up or draining of all borrow-pits. The task is Herculean, but it is of importance that it should be carried out. The drainage could be effected readily by a general levelling of the pits and a rough canalisation of areas between them effecting a drainage of accumulated waters to lower levels. The amount of coolie labour always available in the permanent-way establishment of railways should make this an inexpensive operation.

There is a third factor in operation while railways are under construction—the aggregation of labourers many of whom are already infected with malaria. Such cases, with the presence of malaria-carrying anophelines, rapidly diffuse the disease amongst the non-infected, malarial infection becomes widespread, and so the infection is maintained. As there are many thousands of people constantly so employed in India, and as such employment has gone on for the last fifty years, the influence of this factor in the perpetuation of malaria in India is considerable. It should be a fundamental hygienic principle in the construction of all new railways in India that three important factors—creation of borrow-pits, obstructing the flow of subsoil water, and elimination of cases of malarial infection from amongst coolie labourers—be kept fully in mind if not actually legislated for. Nothing should be done which can render the tract malarious. This is readily carried out by a little forethought and some initial extra labour.

Effects of irrigation canal works.—In the construction of *irrigation canals* we have in addition to the susceptible labourers, who are employed on the main work and its various channels, village populations and so we get malarial infection disseminated throughout the district, in which the maintenance of the malarial parasite is permanently secured by the vast number of breeding grounds created for anophelines through raising of the subsoil water level, and consequent formation of pools of water in the whole of the irrigated area.

One was encamped at Madhopur during a malarious season; that station forms the head of the Bari Doab irrigation works; every house and hut was full of malaria-carrying anophelines. These canals irrigated the fields connected with villages for hundreds of square miles; the water in the fields around villages was bubbling to the surface in hundreds of places; there was no provision for drainage of the subsoil. The extent of the malaria that existed in this camp is referred to on page 28. In such an instance as this no malariologist would recommend that any radical efforts to exterminate mosquitoes be made. Here he would advise mechanical protection from mosquitoes by some means, isolation of infected persons, and quinine prophylaxis. In all such cases there are not only hundreds of breeding pools but new ones are cropping up continually in unexpected places.

Effects of road-making.—Collections of coolies in connection with road construction operate in distributing malaria in the same way as does the making of railway embankments, although to a less extent, as the size of the camps is smaller. The making of roads affects malaria in other ways, which it is convenient to consider here. *Road making* is a prolific source of breeding grounds for mosquitoes. This is especially so in extensive roads on the flat country along the larger rivers (Ganges, Jumna, Brahmaputra, etc.) and along the sea coast. They create these breeding spots by the formation of "borrow-pits" (excavations formed by removing earth for raising the level of the roads above the surrounding areas), * and, when finished, the roads interfere with the proper surface drainage and raise the subsoil water level.

These excavations become veritable nurseries for mosquitoes, the first fall of rain filling them; they become reservoirs of stagnant water that fill with wild grasses, weeds, and vegetation generally, which give cover to larvæ and permit of their multiplication without hindrance. These are amongst the most popular breeding grounds of anophelines. All houses or huts within the radius of flight of anophelines from the roads may therefore be invaded by malaria-carrying mosquitoes. Borrow-pits from road-making form one of the main sources of malaria-carrying anophelines throughout this country and they can be legitimately incriminated in the production of a vast amount of malaria. This has gone on for generations. In all villages along such roads there are never wanting cases of malarial infection to perpetuate the different species of malarial organisms. The process of its dissemination requires no description.

One would here inveigh as forcibly as words can express against the wantonness of such indiscriminate disruption of the soil level in

* Borrow-pits on roads and along railway lines are rectangular excavations running in a continuous chain along one side (or both sides) of the road or line, usually having a column of earth near the centre of each pit to show the depth of the earth removed, and enable the contractor to calculate the quantity of earth used in the roadway or railway embankment.

road-making. It should be rendered an illegal proceeding. It should be legislated on as strictly as has lately been done in the whole of the Panama Canal Zone with such successful results.

When roads in India interfere with land drainage they necessarily raise the level of ground water, and as a result increase the breeding of mosquitoes, and, through the latter, increase the prevalence of malaria. All borrow-pits at the sides of roads and along railway lines are injurious to public health and in India a general source of malaria.

There is scarcely a village in the whole of India that is not surrounded by its borrow-pits ; in most of them such pits are to be found scarring the interior of the village also. These have been created by the villagers themselves by excavating the soil for making mud walls or sun-dried bricks for building purposes.

The manner in which malaria may be considerably reduced amongst gangs of labourers is fully dealt with in Part III.

F.—Theories of Malarial Infection.

It is obvious that until the manner in which malarial infection was brought about in human beings, it was not possible to formulate any rational basis for the general prophylaxis of malaria An enormous amount of work was done after the discovery of malarial parasites in human blood with the view to solve this highly important question, and this work has resulted in a solution of the problem by a complete demonstration of the relationship of the anopheline cycle to malarial parasites. The views held anterior to the discovery of this relationship are in many ways deserving of our attention ; they were chiefly connected with the conveyance of malaria to man (1) through air and (2) water.

Air theory of malarial infection.—The theory that the "poison," "miasm," "germs" or "parasites" of malaria emanate from the soil to the air, and gain access to the human economy through the respiratory tract, is the oldest, and has, throughout the history of malaria, from ancient to comparatively modern times, been the most popular.

Many facts are antagonistic to the air theory. It has long been known that areas of severe malarial infection and those of practical immunity may be in proximity to one another ; this is seen in certain districts in this country ; in the same town one part may be malarious and the other free from malaria ; the people on one side or end of a street suffer from malaria while those of the other does not ; that rooms in one part of a house are decidedly more malarious than the other ; that areas a short distance from and above an unhealthy swamp may be quite free from malaria, whilst, those on a level with and close to it, are very malarious. Every experienced medical man in India can quote instances of this kind. Again, it is well known that the crews of ships anchored near malarious places, so long as they remain on board, do not suffer from malaria, provided the ship is a few hundred yards or so from the shore. We have the frequently quoted case of the freedom of the people dwelling in the Corso in Rome being free from malaria, whilst those living outside the Porta del Popolo, a few hundred yards away, suffering severely from malarial fevers. Were malaria carried by air such limited localisations of the infection would not take place.

The air of malarious regions has been repeatedly investigated with the view to discovering the presence of the malarious parasites. Such observations in modern times have invariably been negative.

Water theory of malarial infection.—An enormous number of so-called facts are to be found in the literature of the epidemiology of malaria connecting the drinking of certain waters with the causation of malarial diseases. Many of these appear, at first sight, to be convincing, but none of them can stand scientific criticism. It may be definitely stated that in no single instance has malaria been produced by the drinking of contaminated water. The proofs adduced in support of the water theory are not scientifically convincing. Practically all the instances advanced can be explained by previous infection in the malarial district. Some of the instances of boardship malaria, such as that of the " Argo, " may be explained in one of several ways—that the cases were not malaria at all (they were not proved to be so by blood examination), or that malaria-infected anophelines were on board, or that persons were infected before going to sea.

To prove that water can convey malaria it would be necessary to export the malaria-conveying water from the malarious district to an assured non-malarious district, and allow persons, who are known never to have suffered from malaria and at the time do not harbour malarial parasites in their blood, to drink such water. If at the end of the maximum period of incubation of malarial fevers such persons did not suffer from pyrexial phenomena associated with malarial parasites in their blood, the proof would fail. A successful experiment of this kind has never been carried out. On the other hand, such experiments have on several occasions been carried out with negative results.

Whilst as a rule in large towns and cities *in malarial districts* the introduction of a public water-supply of the modern description materially lowers the malarial endemicity (for reasons that can be now readily explained), there are several instances on record in small and isolated places in malarious districts in India where the introduction of a pure water-supply has not been followed by any such salutary influence. There are instances in which the introduction of a water-supply not supplemented by adequate drainage has been followed by an increase of the malarial incidence.

In view of all we know of the malarial parasite we cannot believe that it is capable of living in water at a temperature considerably below that of man's blood.

From the foregoing statements it will be obvious that the contributory epidemiological factors regarding malaria almost completely coincide with the mosquito-malaria hypothesis. There are a few gaps in our knowledge, but these are one by one disappearing under further investigation. There are differences in the manner in which these individual factors operate in different places, and the exact relationship of soil, temperature, and rainfall to malaria, can only be worked out by an extensive inquiry regarding their effects in particular places.

Mosquito-malaria hypothesis.—In 1894 MANSON definitely formulated a mosquito-malaria hypothesis, his argument being that as the protozoal organism of malaria is a parasite, to maintain its existence as a species it must pass from host to host, that it must at one phase of its existence live outside the body of man. Further, that as the flagellated body of the male malarial parasites does not come into existence until the blood has left the blood vessels and is outside the human body, he concluded that the flagellated body was the first phase of the life of the parasite outside man. As the parasite in the blood of man is intracorpuscular, and consequently incapable of leaving the body spontaneously, he conceived the view that it was received by some blood-sucking insect common in the regions where malaria was endemic. He believed this insect to be some particular genus of mosquito.

In 1894, MANSON suggested to RONALD ROSS that mosquitoes took gametocytes into their body, that gametes are the means by which mosquitoes may be infected.

RONALD ROSS in 1895 demonstrated the fact that when malignant tertian blood containing crescents is ingested by a mosquito, a large proportion of the crescents rapidly proceed to form microgametes and to throw out flagella. He demonstrated that in particular species of mosquitoes fed on malaria blood, living and growing malarial parasites containing melanin are to be found embedded in the stomach wall of the insects. In 1897 he also demonstrated that if a particular kind of mosquito be fed on the blood of birds containing a malaria-like parasite (*Proteosoma*), the parasite enters the stomach wall of the mosquito, grows and sporulates there, that the resulting sporozoites enter the salivary glands of the insect, and that the insect is then able to infect other birds. He showed that only particular species of mosquitoes can carry this special avian malarial parasite in this way, and that the particular species of mosquito was not efficient as regards another blood parasite of birds, *viz.*, *Halteridium*, or as regards the malarial parasite of man. Ross was the first to prove both by analogy and observation that the phase of the malarial parasite outside the body of man is passed in particular species of mosquitoes, and inferred that the parasite is transferred from man to man by the mosquito.

The method of the discovery of the communicability of malaria from man to man by anophelines is one of the most profoundly interesting subjects in the whole history of medicine, and has done more than any other discovery to stimulate inquiry into the various animal parasites communicable to man through insects and otherwise.* This the world owes to RONALD ROSS.

BIGNAMI in 1898 gave æstivo-autumnal malarial fever to a man by allowing anophelines which had bitten an infected individual to bite a patient who had never had malaria. In the same year BIGNAMI, BASTIENELLA and GRASSI, caused double tertian infection in man by anopheline bites. In 1899 they infected *Anopheles maculipennis* with quartan parasites, and traced the stages of development of the parasite in this mosquito.

GRASSI showed that several species of anophelines are the particular hosts of the malarial parasites of man. He traced the crescent and spherical gametocytes through the mosquito hosts, and found that in their development they were practically identical with what ROSS had shown to be the case in avian malaria. GRASSI'S observations were but the ultimate stage in the completion of ROSS' work.

The mosquito-malaria hypothesis explains almost all the epidemiological phenomena connected with malarial fevers—the period of incubation in the mosquito and the subsequent period of incubation in man; there is a complete analogy between this view and that of other infectious diseases such as yellow fever, relapsing fever, human trypanosomiasis, and tse-tse fly disease in animals, etc.

At no period of their life-history are the plasmodia of malaria found apart from the two hosts—hence the old theories of malaria arising from miasmata in air, or germs in soil or water, are mere matters of history. This is of importance epidemiologically as it excludes the necessity of any efforts being needed to attack the parasities in these supposed sources.

Anophelines biting patients in whom only the schizogonous or asexual phase of the parasite is in progress, is not capable of transmitting malaria—all the young, intermediate, and sporulating forms, are disentegrated and digested in the stomach of the mosquito.

In malarious places during the endemic season there are malarial cases and always a number of malaria-carrying anophelines in whose salivary glands sporozoites are to be found.

Infected anophelines if exported from endemic malarial localities to non-endemic places and made to bite non-immune persons, produce malarial fever. The experiment of transporting malaria-infected anophelines from endemic malarial foci to non-malarious places, and inoculating people who have never been out of these non-malarious places, has more than once been carried out successfully. CELLI'S cases in Rome is an instance in point. The city of Rome itself is non-malarious

* D. C. REES, *Encyclopædia Medica*, Vol. VII, Article *Malaria*.

Infected mosquitoes transported from the Campagna have produced malaria in persons living in Rome. The cases of Dr. THORBURN MANSON, and Mr. WARREN of the London School of Tropical Medicine, are others. These were inoculated by infected anophelines sent from the Roman Campagna and acquired malarial fever; Mr. Warren had not been in any malarious country, and Dr. Manson not since childhood.

Malarial fevers have been said to be endemic in places where anophelines do not exist. This statement needs actual verification, and so far as the question has been investigated scientifically by expert malariologists, it has been negatived. The work of ROSS, STEPHENS AND CHRISTOPHERS, DANIELS, CELLI and others, has shown that where-ever endemic malaria has been investigated, there, not only adult anophelines, but the breeding grounds of their larva, have likewise been discovered. In such places experts have sometimes had to spend days or even weeks in discovering the haunts of adult anophelines and their breeding grounds, but they have always found them where fresh cases of malaria were occurring. In a recent investigation of the malaria of a large district during the malarious season, in every station enquired into, one found infected malaria-carrying anophelines in the huts of natives, and larvæ of corresponding anophelines in breeding places in the neighbourhood of these huts.

Cases of malaria occur at sea after vessels have been away from malarial places for weeks or months; they occur in the highest hill stations in India, etc., where no anophelines exist. They occur in bodies of men in India in winter, on works of railway embankments, canal excavation and clearing, in soldiers, etc., when no anophelines are present. All such cases are instances of relapses of malarial fever and not fresh infections. Anophelines were in the first instance, in all such cases, implicated in inoculating the malarial parasite. There are also instances where the patient gets his first attack of malarial fever remote from anophelines. This is especially seen in persons proceeding home from India. Some people live for years in this country without suffering from malarial fever, yet on going to sea or on reaching Europe, or not for some months after, suffer for the first time. Many such cases are explained by the fact that the patients had been taking quinine while in the endemic malarial locality but gave it up once they got to sea. Such cases were in all probability the victims of malarial infection all the time, the quinine used kept the number of parasites down to such a minimum that no malarial infection was apparent, but was not sufficient to eradicate them. On discontinuing the drug, the parasite, no longer destroyed or limited in numbers by the quinine, begin to multiply unhindered and finally cause the paroxysms. An occasional case of this kind may arise in which no satisfactory explanation can be arrived at, but the writer has not during the last ten years, that is, since the mosquito-borne theory of malaria become known, met with such a case.

A non-malarious region, having certain species of anophelines, remains such so long as there is an absence of malarial infected human beings. With the accession of the latter a healthy place may become malarious. A mildly-malarious region contiguous to a very malarious one, may, during epidemic malaria in the latter, become severely malarious by the gradual extension of the habitat of malaria-infected anophelines. This occurs during every year of severe epidemic malaria in this country.

It has been definitely shown that (1) the extinction of anophelines in a malaria district practically removes malarial infectiou; and (2) that the rigid use of mosquito nets or dwelling in mosquito-proof houses, without any other prophylactic measures, is capable of preventing malaria in the most virulent malarial districts.

If infected anophelines are kept from biting healthy persons malaria does not occur in the latter. DRS. LOW, SAMBON and REES, of the London School of Tropical Medicine, had constructed in one of the most malarious portions of the swamp land of the Roman Campagna, a small house that was thoroughly protected by mosquito-proof wire-gauze doors and windows. The house was occupied by a number of people, during the malarious season and the breeding time of anophelines, whose movements were not restricted except that they entered the house every evening at sundown and remained inside during the daylight. The night air was admitted freely, and during the rainy season the experimenters purposely got repeated soakings in the rain. They did not take quinine prophylactically. None contracted malaria, whilst their neighbours, who were not protected from mosquitoes, suffered severely.

Four species of anophelines are natural carriers of malaria in India.—So far only four species of anophelines are found to be natural carriers of malaria. It is probable that certain others of the indigenous anophelines will in the future be found to be malaria-carriers, and it is also probable that some of them will not. It is possible that in the case of some of these latter they have, by centuries of repeated infection, worked out for themselves a complete racial immunity to the sporogonous cycle of the plasmodia of malaria. It may also be that in India such possible immuuity in some anophelines explains why in certain districts with knowu malaria-carrying anophelines, malaria has not acquired auything like permanent endemicity, that is, that anophelines known to be malaria-carriers in one district may uot be so in other remote districts by reason of the acquired racial immunity. These hypotheses, carried to a less extent, may be the explanation of the different degrees of variation in prevalence in parts of the same locality. Anophelines, we know, are more or less local in their habits.

It is possible also that there are iu malaria-carrying anophelines varying degrees of susceptibility to infection by the sexual forms of malarial parasites. We know that a degree of relative immunity to the schozogonous phases of malarial parasites may be acquired by man living continuously in endemic malarious places. It is reasonable to suppose that the mosquito through generations of infection may also acquire some degree of insusceptibility, if not of acquired immunity. It is certain that experimenters with malaria-carrying anophelines have met with very varying degrees of success in their experimental malarial inoculations, that the percentage of known anopheline malaria-carriers that can be infected varies within wide limits, and that in many instances they have completely failed. Such hypotheses as these can only be tested by prolonged and laborious investigations connected with such points carried out in the endemic areas. SCHAUDINN believed that certain species of anophelines may be naturally immune against malarial parasites. Such an immunity if acquired by a whole species would account for malarial diseases having died out in localities where it was formerly abundant as in the Eastern Counties of England, where *A. maculipennis*, a known malaria-carrier, is still to be found.

The same conditions that cause a reduction in the incidence of malaria in an endemic area—judicious cultivation, drainage, etc., reduced likewise the prevalence of mosquitoes.—(LAVERAN).

It is now satisfactorily proved that uninhabited regions, although they may be densely populated by anophelines, are free from risks as regards malarial infection. "Infected mosquitoes occur only in the immediate neighbourhood of settlements of infected individuals." Members of exploring expeditions have often remained free from malarial disease so long as they have been in regions remote from such settlements. Sailors who do not go ashore in endemic malarial places escape malarial fever because they have not been bitten by malaria-infected mosquitoes.

The long known view that exposure in the evening, at night and in the early morning, in endemic malarious places is dangerous, is now fully explained by the nocturnal habits of anophelines.

From their structure, vast numbers, and ability to fly, mosquitoes are endowed with potentialities which facilitate their dissemination of disease.

There are some places where endemic malaria is strictly limited to the areas in which anophelines are found: this is especially the case where, say of two villages, one on highland and the other at the foot of hills, the people of the latter only suffer from malarial infections. This was forcibly impressed on one in Manipur, where there are Naga villages on the spurs and tops of some low hills in which the people did not suffer from malarial fevers, whereas, in the villages at the foot of the hills only 300 or 400 feet below, the endemic malarial index was in some cases as high as 73 per cent. In Constantine, Algiers, mosquitoes and malarial fever occur in the valley of the Runniel and are absent on the high parts of the town. This is also particularly seen in the Campagna Romana, where virulent malaria exists, whilst in Rome close by, there is none. The small Island of Chole, in German East Africa, is free from malaria whilst the adjacent mainland is malarious. The Island of St. Lucia is malarious and anophelines are in abundance ; the Islands of Barbadoes and Bermuda, in the same geographical regions, have neither malaria nor anophelines.

The fact that malarial fevers do not begin to occur in large numbers until a month after the rains have commenced (and consequently when anophelines are found in large numbers), bears out, if any other evidence were necessary, the part that these mosquitoes play in the transmission of malaria. When fresh infections of malarial fevers once begin the number of persons infected grows apace, and they do so in proportion to the number of infected anophelines.

The period of the commencement of the regular malarious season is about 30 odd days after the beginning of the rains—this is allowing 14 days for æstvated anophelines to breed a new generation of winged insects, 10 days for infected young anophelines to infect man, and 6 to 10 days for the parasites inoculated into man to multiply sufficiently to give rise to paroxysms of malaria. There is some evidence to the effect that anophelines which become infected during the spring may infect man after æstivation—the same possibly holds good regarding infected hibernating anophelines after they come forth in spring.

A large number of infected anophelines continue to live and thrive for a fairly long time after conditions favouring the breeding of mosquitoes no longer exist. Consequently fresh infections of malarial fevers continue until the commencement of the cold weather. Anophelines have been known to infect man in Northern India (Attock) as late as the 14th November. When the cold weather has really set in gametes of malaria can no longer continue to develop in the mosquito and fresh infections cease.

"It is generally quite possible to give a fair idea of the monthly distribution of rainfall in any warm climate from the returns of sickness and mortality and *vice versâ*."*

That the mosquito is the medium through which malaria is transmitted from man to man is now a recognised fact and not a problematic hypothesis. All stages of the life cycle of all known varieties of malarial parasites have been followed in the human being and in the different species of anophelines that transmit malaria from man to man. Healthy men cannot infect anophelines that have been bred from ova, larva or pupa.

The anopheline factor does not altogther explain the absence, fluctuations and relative intensity of malaria in certain areas, nor does it alone always afford a satisfactory reason for the occurrence of epidemics, or the permanent exultation of malaria characteristic of certain areas.

There may be abundant anophelines with few cases of malarial fever or a large number of malarial fever cases with few anophelines.

* GILES, *Climate and Health in Hot Countries*, p. 105.

These are points in the epidemiology still requiring investigation. In a later Section an attempt is made to explain the reasons for such occurrences.

We may now state that practically all the main facts connected with the epidemiology of malarial fevers are explained satisfactorily by the dissemination of malarial infection through certain anophelines. No solid proof is yet to hand to show that malarial fevers are produced in any other definite way. The cases cited of people acquiring malarial fever the day they arrive in a reputedly malarious place cannot bear scientific examination ; in such instances it is possible that malarial infection was due to previous mosquito bites of which the patient was unconscious, or that they were relapses, or that these cases were some other form of fever.

The discovery of the fact that anophelines convey malaria was not made in a day ; it was not the result of any sudden inspiration, nor does it depend on any superficial considerations. Each link of the chain of evidence has been carefully examined and the conclusion is firmly based on numbers of experiments and observations by many investigators and trained experts with scientific minds.

DEFINITIVE HOSTS OF HUMAN MALARIAL PARASITES.

A.—Indian Mosquitoes and their Habits.

Factors required to produce malaria :—(1) *Anopheline mosquitoes.*—As far as we know no other forms of mosquitoes, or other insects, can act as carriers, though we have still to admit the possibility of such an occurrence until the subject is worked out.

(2) The *present or recent* existence *of cases of malarial fever*—including relapses and cases of malarial infection acquired in other regions who have come to the district.

(3) *External physical conditions*—climate, moisture, temperature, and season favouring the attacks of the mosquito, suitable for its infection, and for further development of the sexual form of the malarial parasite.

(4) *Susceptibility of the mosquito and of the individual bitten to infection.* *

In the absence of any one of these conditions an outbreak of malaria is, as far as we know at present, impossible. There are many places where anophelines exist without malaria ; others in which there is no malaria at particular seasons, because the conditions at these seasons are unfavourable to the development of the mature forms of the parasite, or the gnats do not bite.

* Theyer in Allbutt and Rolleston's *System of Medicine*, Vol. II, Part II, p. 243.

As far as we know malaria is not acquired in uninhabited places; and it certainly has not been proved to do so. There is no spontaneous generation of malaria anywhere. Certain factors must be present whenever it is met with.

In the foregoing pages facts in proof of these statements were brought forward.

Accepting these scientific views as to the nature of malarial infection, we also recognise that there must always be a period of incubation in malarial fevers after the bite of infected mosquitoes, just as we know there is in yellow fever after the bite of the infected *Stegomyia fasciata*, and in sleeping sickness after the introduction of the *Trypanosoma gambiense* by the *Glossina palpalis.*

There is still some difficulty in persuading many intelligent officials that the malaria-carrying power of mosquitoes lies at the foundation of our known anti-malarial measures. One is constantly meeting military and civilian officers who express incredulity regarding the relationship between malaria and anophelines.

Importance of the study of the life-history of mosquitoes.—The study of the life-history of mosquitoes is very important in this country, considering that many kinds of mosquitoes may be the carriers of parasites. The part played by them in the dissemination of certain special diseases are of great significance to the medical officer. They not only convey the germs of certain diseases, but assume the rôle of host in whom diseased micro-organisms pass part of their life cycle. Mosquitoes are important factors in connection with malarial fevers, yellow fever, filariasis and possibly dengue and other diseases. Whilst the manner in which the mosquito is concerned with the dissemination of yellow fever is still *sub judice*, its relations to malarial fevers and filariasis are definitely known. Hence much attention has been given to the life-history, habits, and structure of gnats in recent times in India.

Anophelines the only known carriers of malaria.—There is no evidence at present that other mosquitoes than anophelines can act as hosts of malarial parasites. We cannot definitely assert that some species of Culex, and even some of the genus Stegomyia, which are so universally represented in this country, may not be carriers of malaria; we know positively that certain species of Culex cannot carry human malaria, and none have so far been shown to be malaria-carriers.

Number of known species of mosquitoes.—About 800 mosquitoes have been classified and described. Comparatively few only of those are connected with disease. The vast majority are wild or sylvan mosquitoes, and, as would be expected, their habits are not so well known as the domestic kinds. Up to the present altogether about 119 species of Anophelina, including 27 species in India, have been described. Some of these are of a doubtful nature, and some two dozens are founded on very uncertain characters, and will probably prove to be merely varieties of other species.

Basis of classification of mosquitoes.—In the early days of mosquito investigation, and when there were only three genera, the classification was based on the characters of the palpi—that in both male and female *Anopheles* being long, in *Culex* the male long and female short, and in *Aedis* in both sexes short. It was subsequently found when many fresh genera were created, that palpal characters are insufficient for a classification, although for individual peculiarities useful for distinguishing species. "The characters most constantly found and most easily observed, and by which previous existing genera could be split up into smaller groups, were shown to be the *scales of the head, body, wings, etc.* Scales are particularly characteristic of the whole family *Culicidæ*." The relative arrangement of the three forms of scales on the head, *viz.*, long-curved, upright forked, and flat imbricated, as well as those on the thorax, abdomen and scutellum, are of great importance in the new classification of mosquitoes.

What are mosquitoes ?—Mosquitoes are two-winged flies (Diptera) of the family *Culicidæ.* To duly comprehend the life cycle of the parasities of malaria, etc., in mosquitoes, it is necessary that we should possess some knowledge of the anatomical structure of these insects.

General characters of mosquitoes.—" Mosquitoes, as in other six-footed flies, are provided with a head, thorax and abdomen. The head bears the mouth-parts drawn out into a long penetrating proboscis, which latter is often as long, or even longer than the whole body. The head, thorax and body of all Culex mosquitoes are covered with distinctive scales; but in the *Anophelina* these may only occur on the head, the thorax and abdomen being hairy."

All mosquitoes except the small genera of *Corethrina* and *Mochlonyx* are provided with a long suctorial proboscis.

The *Corethrina* have mouth parts formed on the same pattern as midges, which is a short bilobed apparatus, instead of the long piercing proboscis of mosquitoes.

From *Chirominidæ* or midges, mosquitoes are distinguished by the fact that all the veins of the wings are fringed with scales like those of butterflies and moths.

Metamorphosis of mosquitoes.—All mosquitoes undergo a complete metamorphosis, that is, there is an active, growing and feeding stage, the *larva*; a non-growing stage, the *pupa*, during which stage the larva is transformed into the active flying sexual adult—the mosquito.

Head.—On each side of the head there is a compound eye, larger in the male. The eyes are often brightly coloured during life. Between the eyes above is the *occiput*, and in front the *vertex*, and at the back of the head is the *nape*. The part between the eyes is the *frons*. The head is covered (more or less) with scales and bristles (*chetæ*). Projecting forward from the head is the *clypeus*, which consists of a blunt process with distinctive characters in different genera of mosquitoes.

Mouth.—The *mouth* is prolonged into a long sucking and piercing tube called the *proboscis*, which is straight in most genera. The mouth-parts constituting the proboscis are—the *labium*, *epipharynx* or upper lip, two sharp lancet-like needles—the *mandibles*, two pointed *maxillæ*; a single flattened process—the *hypopharynx*, and the large gutter-shaped lower lip or *labium*, which ends in two pointed processes—the *labella*. The labium is fleshy, covered with scales outside and deeply grooved within; when at rest the groove contains the piercing mouth-parts. Closing on the groove above is the labrum, with the epipharynx, with which it is fused. Beneath it is the hypopharynx, which is flat, and forms with the labium the tube by which the blood is drawn into the mosquito's body; the hypopharynx is perforated by the salivary duct, and down this tube the saliva is injected into the wound caused by the insect. The fleshy lip acts as a protecting organ to the more delicate cutting parts of the mouth, all of which latter penetrate the skin in the act of feeding, whilst the labium remains outside, the penetrating organs passing between the bent labella. The whole labium guides them in the process. The male mandibles and maxilla are usually very rudimentary, hence they do not bite.

Palpi.—Attached to the mouth are the palps (*palpi*) which were formerly used in the classification of mosquitoes. They are composed of two or more segments. In some mosquitoes they are very short in both male and female *Ædinæ*, in others long in both sexes (*Anophelinæ*), in others again long in the male and short in the female (*Culicinæ*).

Antennæ.—The antennæ are composed of a large basal segment and a long flagellum consisting of many segments. In the female the segments are provided with short hairs arranged in circles, in the males the antennæ are usually plumose. It is considered that some of the hairs on the antennæ are auditory in function as they respond to sound by a vibratory motion, but the halteres or balancers are probably the chief auditory organs of mosquitoes. The antennæ however are turned in the direction of sounds, the head turning at the same time.

Method of breathing and producing sound.—Mosquitoes breathe through the sides of the body. The buzzing sound of a mosquito is produced not by the wings but by the vibration of a peculiarly constructed chitinous process situated near the breathing apertures, and set in vibratory motion by respiration, in the same way that the song of flies is produced.

Thorax.—This region forms a large area situated between the head and abdomen. The greater part of it is composed of the *meso-thorax* or mid-thorax, which has at the back part a sharply restricted piece called the *scutellum*, which in *Anophelinæ* presents a simple rounded posterior border, whilst in other sub-families it is distinctly trilobed. The *prothorax* consists of two lateral processes called the prothorax lobes. The hind part of the thorax, called the *metathorax*, is rounded and located beneath the scutellum; at the sides are plates constituting the *pluerœ*, which are of no value for identification. The whole thorax may be covered with scales, but as a rule the meta-thorax is bare; it may, however, carry both chetæ and scales. The wings and legs are attached to the thorax—the wings to the upper portion and the legs to the sides of the pleuræ.

Wings.—The wings spring from the sides of the mesonotum towards its posterior end, whilst attached to the metathorax are the *halteres* or balancers—a pair of club-shaped processes which are the remnants of the second pair of wings of four-winged insects. The *venation of the wing* is somewhat complex. The main points in connection with the wings are the *costal vein*, the *longitudinal veins* and the *wing fringe*. The *costal vein* runs around the entire border of the wing, in all but the *Heptaphlebomyinæ* there are *six longitudinal veins*. Below the upper border of the costa and arising from the root of the wing is the *sub-costal vein*, which joins the costal vein before the tip of the wing, beneath it is the *first longitudinal* vein, which ends near the tip of the wing. The *second longitudinal vein* arises from the first, and ends in two branches which form the so-called *first sub-marginal cell* (sometimes called the first *fork-cell*). The *third long vein* is simple and arises at or near the junction of *two cross-veins*, the *supernumerary* and the *mid*; this vein is of importance in identifying several species of Indian Anophelinæ. The *fourth* arises from the base of the wing and terminates in two branches which form the *second posterior cell* (or second fork-cell). The *fifth* also arises from the base of the wing and sends off a branch about half its length. The fifth and *sixth* veins are both simple and both arise from the base of the wing.

Legs.—The legs are attached to the pro-meso and meta-thoracic rings on the lower part of the pleura. Each leg consists of nine segments. The one at the base, by means of which they are attached to the body, is called the *coxa*, then comes a small segment called the *trochanter*, succeeded by the large *femur*, then the *tibia* and the *foot;* the last named is made up of fine segments, the basal one of which is much the longest and called the *metatarsus*; the four remaining segments constitute the tarsus. The femora and tibiæ are often bristly and there may be spines on all the parts, which are always covered with closely oppressed or outstanding scales. The fifth segment of the foot ends in two claws or ungues.

Ungues.—The ungues or claws are two in number to each foot; these are always *equal* in the *female; in the male* the fore and the mid pair are always unequal in size, whilst the posterior ones are the same in size. The ungues in the female may be simple or uni-serrated; in the male, the fore and mid ungues may be uni-, bi-, or even tri-serrated. Mosquitoes adhere to a wall just as a cat clings to the bark of a tree, by its claws. It cannot adhere to an absolutely smooth perpendicular surface in the same way that a fly can; a fly's foot acts as a sucker, while the feet of the mosquito have claws. We sometimes see mosquitoes on panes of glass. this is because on the pane there is (except just after cleaning) enough dust and moisture to form a film on the glass which gives mosquitoes a foothold.

Abdomen.—The abdomen consists of eight segments, in the *female ending* in *two lobes*, and in the *male* in *distinct genitalia*, consisting of *basal lobes, claspers* and various prominences. The male genitalia are useful character for separating very closely allied species. Except in the true *Anopheles* the abdomen is more or less coated with scales, and may have lateral tufts of scales and bristles. Each segment has a row or rows of bristles along its posterior border and frequently many at the apex.

Scales of mosquitoes.—The most characteristic structure by which mosquitoes can be grouped and identified are the scales. The *scales of the head* are usually in three forms—*narrow-curved, upright-forked*, and *flat*. The *scales of the thorax* are *narrow-curved, hair like curved, spindle-shaped, flat*, and *twisted*. No upright-forked scales occur on the thorax or abdomen. On the *abdomen* the scales are usually *flat*, but may be spindle-shaped (*Cellia*), narrow-curved (*Pyretophorus*), or twisted upright scales (*Macidus*). The *scales of the wings* are very varied—narrow, straight, linear scales (*Culex*), short, broad, flat scales (*Melucoconion*), broad, straight scales (*Tænio-rhynchus*), very broad, flat, asymmetrical scales (*Mansonia*), and long and short lanceolate scales (*Anopheles* and *Pyretophorus*), etc.

The scales of the *wing fringe* are of three series—long and short fringe scales which are pointed, and small border scales which vary in form, some spatulate, others of the Mansonia type. Each vein has median scales, which usually differ in form.

Halteres or balancers.—These consist of basal swellings, a narrow stem and a swollen cup-shaped or funnel-shaped knot, which is usually scaly. They lie behind the wings and represent the hinder wings of four-winged insects. In mosquitoes these are probably the chief part of their auditory apparatus.

Internal anatomy.—The alimentary tract and its accessory organs, the stomach and salivary glands, are the most important parts, because in them in anophelines are developed the sexual forms of the malarial parasites of men.

The *alimentary canal* begins, it may be said, at the apex of the proboscis and ends at the terminal anus. A *pumping organ* sucks the blood up through the tube formed of the labrum and hypopharynx. The hypopharynx is perforated by a small tube connected with the salivary glands through which the saliva is ejected when the mosquito bites. Behind the clypeus the different mouth-parts unite to form what may be considered *the mouth*. Following the mouth is the *buccal cavity* which opens into the pharynx by a valvular arrangement. The *pharynx* or pumping organ extends from the buccal cavity through the head or near the back of the head, where it joins the œsophagus. At its commencement it is tubular, but lower down dilates; it is much larger in the female than the male; it is partly chitinous. The œsophagus extends from the pharynx to the so-called *œsophageal valve*. Running from the œsophagus are three large blind sacs—food reservoirs, one ventral and two latero-dorsal. The large ventral reservoir extends back to the seventh segment when filled with blood or vegetable fluids. The valve lies between the œsophagus and midgut.

Midgut.—This is the largest part of the alimentary canal, and consists of a straight tube running from the œsophageal valve to the stomach near the end of the body (that is, about the level of the sixth abdominal segment). *The stomach itself is the posterior dilated part of the midgut*, and it is in it that malarial parasites develop.

The *hindgut* begins where the Malpighian tubes arise. It is short, slightly flexed, and ends in the anus.

alivary glands.—The salivary duct is not connected with the alimentary canal. The saliva is ejected by the hypopharynx *viâ* the canal arched over by fine lamellæ. At the base of the hypopharynx is a structure connecting the common salivary duct and the groove. This is a pump depending for its function on the powerful voluntary muscles around it. The common salivary duct ends in the centre of a chitinous membrane which is continuous with a highly chitinous cup opening into the hypopharynx.

The duct passes back beneath the valve of the buccal cavity where it divides into ducts of similar structure. The two salivary ducts run parallel along the ventral wall of the neck into the thoracic cavity; on reaching this region they diverge and branch into the salivary glands.

Each salivary gland consists of three blind sacs, which vary in position as the glands have to accommodate themselves to the position a of the very powerful thoracic muscles which propel the wings. The glands are trilobed, surrounded by *fat-bodies*, and are very large in proportion to the size of the mosquito. The three lobes of each gland are composed of acini of the same structure as the common duct.

Malpighian tubes.—These are developed in the larva and open at the same level into the hindgut at the junction of the midgut. They are five in number and lie freely bathed in the fluids of the hæmocœl. They have a pale yellow colour with transmitted or reflected light. Their function is chiefly excretory.

Genital organs.—In the *female* these consist of the two *ovaries* opening into a common duct by the ovarian tubules. Into the common tube opens a mucous gland, and also, by a long thin duct, the *spermathecæ*, which are chitinous sacs, acting as reservoirs for the spermatozoa.

The male genitals consist of two testes united by *vasa deferentia* to the ejaculatory duct; to each vas deferens is attached a short sac, the *receptaculum seminis*. The penis is soft and fleshy and is placed between two internal claspers, etc., and on each side of these are large *external claspers*, which are of diagnostic value. The spermatozoa have a round head with a flagellum.*

Differentiation between *Culicinæ* and *Anophelinæ*.—The following table will enable us to distinguish the ova, larvæ, and adults of *Culicinæ* and *Anophelinæ*, it being understood that the characteristics given are those of the sub-families, and in no sense specific:—

CULICINÆ.	ANOPHELINÆ.
Eggs.—Laid in rafts, individual eggs bottle or cartridge-shaped. Found in artifical collections of water which are often dirty.	Laid singly and then forming triangles or other geometrical figures; in the water, individual eggs boat-shaped, each with ends like the raised prow and stern of a boat, and ribbed laterally (float cells containing air), the ribs looking like oars. The eggs sometimes occur separately and are then found touching particles of leaves or vegetable débris. The eggs are found in natural or terrestrial collections of water.

* I am indebted to Mr. F. V. THEOBALD'S Article on *Culicidæ* in ALLBUTT and ROLLESTON'S *System of Medicine*, Part II, Vol. II, for this account of the anatomical structure of mosquitoes.

	Culicinæ.	*Anophelinæ.*
Larvæ.	Long breathing tube (*siphon*) near the tail, and a large number of air-vessels which distribute air to all tissues of the body. It is attached to water by surface tension. If the surface of the water is covered with oil, the larvæ sink. They float head downwards. Their normal position is at the surface, but they wriggle to the bottom on being disturbed. Culex larvæ cannot live at the bottom of water, there they would soon die. When changing their skin they can float flat, but never to the same extent as anophelines larvæ. They are found in artificial collections of water—tubs, cisterns, chatties, kerosene oil tins, pots, pans, broken bottles, etc.	Have no breathing tube. They breathe through two apertures at the back of 8th abdominal segment of the body. They float flat by surface tension with their palmate hairs. When disturbed they skate backwards. They are found in terrestrial water. A few species may be found in artificial collections of water, *e.g.*, *Nys. stephensi* in chatties and wells.
Adult Mosquitoes.	Short *palpi* in female. They *sit flat* or only with a slight angle to the surface on which they are resting. The *wings* are plain and not spotted. The body is unshapely and somewhat hunchbacked. The thorax is large. They are grey, sombre, or dusky-coloured.	Long *palpi* in female. Angular position to surface on which resting—tends to stand on its head as it were—the proboscis, head and body being at an angle to the wall or surface on which resting. The wings are *spotted.* The body is graceful and shapely, the head tapers into the proboscis. If the anterior border of the wing has three or four spots it is certainly an anopheline.
Breeding Places.	Tubs, ditches, garden cisterns, drains for rain-water, etc. In temperate climates they often choose terrestrial waters—they do not do so in the tropics.	Terrestrial waters—rivers, streams, canals, lakes, pools, ponds. all large collections of water, rain-water runlets.

The method of identifying mosquitoes is comparatively easy after the basis upon which they are classified is thoroughly understood. A few hours spent with some one who has acquired the habit of identifying and grouping mosquitoes into genera, and collected eggs and larvæ for demonstration, is more profitable to the uninitiated than weeks of perusal of descriptions and studying plates and diagrams.

All Culicidæ are aquatic in their larval and pupal stages and live in water. They swim and dive by means of paddles and feed on water organisms. They cannot breathe under water. In a week or more pupa is formed from the larva. Larvæ vary from $\frac{1}{16}$ to $\frac{1}{4}$ of an inch in length, the latter being their length when full grown. Their colour varies, most are brown, yellow or greenish.

Ova of mosquitoes.—The *ova* of mosquitoes vary considerably in shape and arrangement. Some are laid in comparatively large masses called egg-rafts, the eggs being arranged side by side in their long axis—this occurs in most of the Culicina. Some are laid with a long ribbon-like arrangement (Tæniorhynchus), and others quite separately—Anophelina, Stegomyia, and Joblotina. The eggs hatch into larva in from a few hours to a few days, varying with the temperature of the water and kind of mosquito. The eggs of different species of the one genus differ very materially from those of other species of the same genus. In *Anophelinæ*, the eggs have an oval outline and are provided with distinct *lateral floats*. The form and general arrangement of the floats are important for the differentiation of different species of anophe-line eggs. The eggs of mosquitoes always float. Complete immersion seems to destroy them.

Larvæ of Anophelinæ.—The characters of the larvæ of Culex, Stegomyia, and Anophelina are given on pages 60, 61, and 73, respectively, and in the table on page 52.

In both the larval and pupal stages air is needed; to obtain it the breathing tubes must at frequent intervals protrude from the water surface into the air above. A film of oil placed on the surface of the water can prevent the breathing tubes from reaching the air and in this way cause death both in the larval and pupal stages. When first hatched out larvæ are only just visible to the naked eye. The duration of the existence of larvæ is closely related to the temperature of the water and the amount of food available.

Larvæ and pupæ are best preserved in rectified spirit, or in 4 per cent. solution of formalin, each capture being placed in a separate tube in which should also be enclosed a scrap of paper written in Indian ink giving date and place of capture, character of the water, notes on colour and any other information necessary. The tube should not be corked or sealed; a piece of muslin should be tied over the mouth and placed in a bottle with a large mouth with other tubes containing specimens of larvæ. The larger bottle should also be placed in spirit or other preservative similar to that in the tubes. The muslin protects the tubes from the effects of jolting in carriage. If required for dissection subsequently, they should be placed in the usual laboratory graduated percentages of alcohol until pure alcohol is reached and then returned to 90 per cent alcohol. For ordinary routine work in India methylated spirit answers very well. Adult mosquitoes required for identification should not be placed in spirit as in it they lose their colours.

Period of development from egg to imago or adult mosquito.—The period elapsing from egg to adult is, under favourable circumstances, from a week to 21 days—determined by the kind of larva, temperature, and general meteorological conditions—in warm moist weather with slight rain their development is rapid; whereas stormy, cold and wintry weather retards their development; abundance of food favours the development of larvæ. In pure water their development may be delayed for weeks, their development is also delayed *in vitro* or artificial hatching out.

Enemies of larvæ.—There are many enemies of larvæ in natural waters, specially in large rivers, lakes and tanks, and these consist chiefly of fish, frogs, tadpoles, and larvæ of other larger insects; the larvæ of dragon-flies are special enemies of mosquito larva. Constant disturbance of water is unfavourable to their development, as they usually require still water; winds, which create surface waves, cause them to drift about or drive them to the bottom, and generally act detrimentally on them. In rivers and streams we find them at the margins, attached to or under cover of leaves, grass, water plants, vegetable débris, etc. Similarly, in canals they are mostly at the margins. In canals the rate of flow is regular and less boisterous than that of rivers and streams, hence they are favourite breeding grounds. In lakes we also find them near the edges. Lakes are generally stocked with many enemies of larvæ, and the mosquito in laying eggs selects the shallower parts, sides and margins. In ponds also they are close to the edges. Minnows and what are called "millions" appear to gloat over mosquito larvæ, as do also sticklebacks, carp, etc. Frequently, however, small fish and larvæ live amicably in the open waters of rice-fields, tanks and marshes. "The predaceous larvæ of dragon-flies and water-beetles devour the larvæ and pupæ of mosquitoes. Adult mosquitoes are preyed upon by dragon-flies, insectivorous and many night-flying birds, such as night hawks and flying bats everywhere, but mosquitoes multiply rapidly, and their numbers are so immense that their prevalence is only slightly restricted by natural enemies."

In the natural state there is annually an enormous depopulation of mosquitoes by the drying up of collections of water used as feeding grounds by mosquitoes.

The main provision of larvæ is found in the minute vegetable organisms, especially the spores of algæ, which are abundant in the situations where they are common, the culicine larvæ confining themselves mainly to those that are found completely immersed, while young anophelines brouse on those floating on the surface, keeping its head screwed round a full half turn so as to bring the mouth uppermost. They also consume small crustaceous and other water insects. Some are said to be cannibalistic—especially is this so with the large larvæ of *Megarhinina*, *Toxorhynchus* and *Mucidus*, who devour one another greedily.

Pupæ.—Like all insects, the mosquito passes from the larval to the pupal stage. The pupa is a curved, comma-shaped, active little animal, which wriggles about in a series of curious jerky movements in the water, coming to the surface constantly to breathe. They are, however, less energetic than larvæ, and are generally seen floating on the surface. When fully developed they have all the structure of adults. The duration of pupal life is short, in some only 48 hours, but it may be 10 or 12 days. Temperature affects the period of its development greatly. Pupæ are usually brown or greenish in colour, some have a dull reddish hue. After two or more days the pupal skin splits and sets the imago free. The imago emerges from the pupal case which it leaves on the water. The imago after emergence rests on the pupal case for a few hours to dry its wings and then flies away.

Breeding places of mosquitoes.—Mosquitoes may be looked upon as forming colonies adjacent to their breeding grounds. "The vast majority remain close to where they were born." Comparatively few migrate thence. "To suppose that the mosquito population will remain the same after local suppression of breeding is equivalent to supposing that the human population of Great Britain would not be affected by abolishing the birth rate."*

Under normal circumstances the immigration and emigration of mosquitoes may be assumed to be equal except in highly endemic areas and during intensely malarial seasons in such areas, when the former in all probability exceeds the latter, because the conditions for their rapid multiplication are in existence in such areas and at such times. It may be assumed also that mosquitoes decrease in numbers the further the distance from their breeding grounds, and whilst the actual ratio of such decrease cannot be estimated by any known mathematical formulæ, the fact that anophelines are naturally weak fliers supports such a supposition.

In every endemic malarial district where malaria has been investigated by experts, there anophelines have been found, and this after their absence has been repeatedly asserted. It is often forgotten that anophelines, though naturally breeding in terrestrial waters, may, in the absence of the latter, vicariously breed in any collection of water; they have been actually found breeding in cess-pits, and *Nys. stephensi*, a known malaria-carrier, has been found by myself and others on several occasions in earthenware chatties and wells when other terrestrial breeding places were also available.

* RONALD ROSS in ALLBUTT and ROLLESTON'S *System of Medicine*, Vol. II, Part II, p. 278.

One personally believes it to be possible that anophelines may in the course of long periods, after many generations of infection with the sexual forms of human malarial parasites, work out for themselves a racial immunity against this infection. Further that such inherited immunity may be quite localised. This assumes that *anophelines are not extensive travellers*, and that they, like all other members of the animal creation, prefer to dwell in the vicinity in which they were born, except when compelled by local environment to quit their native home.

Mosquitoes decrease as the distance from their breeding places increases, and in general terms it may be stated that their number in a locality is in inverse ratio to the square of its distance from breeding places. An area containing a certain number, say, a mile from a habitation, the number at $\frac{1}{4}$ of a mile from the breeding place would be $\frac{1}{2}$, at $\frac{1}{2}$ a mile $\frac{1}{4}$, at $\frac{3}{4}$ mile $\frac{1}{9}$, at a mile $\frac{1}{16}$, and so on (RONALD ROSS). A small pool near at hand is thus seen to be always a more likely source of infection than a large marsh a mile away. This inversion of the square of the distance from breeding places regulates to some extent the number of mosquitoes in special localities. A thick and dense jungle at some distance from habitations cannot be penetrated by anophelines, so that initially, at least, it is unnecessary to remove such. In some instances such removal may do harm, as where breeding grounds are on the far side of such jungle away from houses.

Pools and collections of water near houses are very important. If pools are distant from houses, mosquitoes may have to fly from their breeding places to such houses, and it is fairly well known now that where the breeding grounds are thus distant, mosquitoes do not appear in large numbers in human dwellings.

Pools connected with rivers, irrigation channels, gardens, etc., are favourite breeding grounds of anophelines. They contain abundance of food in the form of lower plants, such as algæ, etc.

In every case a careful search for every possible kind of water collection is necessary before declaring that larvæ do not exist. One has never failed to find larvæ of malaria-carrying anophelines in endemic malarial places during the breeding season.

All the greatest investigators of malaria in India assure us that "there is no collection of water, however insignificant, which it is safe to disregard as a possible source of larvæ. There are few places however dry where by careful search some unexpected source of water will not be found, and the existence of mosquitoes, otherwise difficult to account for, readily explained" (J. W. W. STEPHENS). The same opinion is expressed by JAMES and LISTON* and by RONALD ROSS. When there is an absence of the particular breeding ground that different species of anophelines would select, they will breed in any collection of water.

*Anopheles Mosquitoes of India, p. 48.

Time mosquitoes bite.—The majority of Indian mosquitoes prefer biting at night. During the day they obscure themselves amongst shrubs and bushes, in dark corners of native huts, tents and houses. Some favour dark objects, dark clothing being particularly attractive. The specially domestic kinds, such as the *Culex fatigans*, and *Stegomyia fasciata* and *S. asiatica*, are not often seen remote from habitations, but sometimes may be found in jungles. Occasionally some of the wild or sylvan mosquitoes, contrary to their usual habits, may be found in houses, huts, and habitations generally. One has found specimens of both *Mr. nigerrimus* and *Mr. barbirostris* in native huts.

Food of mosquitoes.—The majority of mosquitoes never taste man's blood, and but comparatively few take vertebrate blood. Certain species are, however, natural blood-suckers, especially the Stegomyias, and certain species of Culex and Anophelinæ. Most mosquitoes feed on vegetable juices. They are very partial to bananas; and sliced bananas is one of the best foods to keep them alive. Many mosquitoes take the blood of invertebrate animals, such as insects. They also feed on young fish. It is curious that certain species which suck man's blood in some parts of the world do not do so in others. "*Anopheles maculipennis*, a proved malaria-carrier, bites viciously in many parts of Europe, but in some districts of Britain is never known to bite man. The same applies to *Culex pipiens*." It is the female alone that sucks blood—the males are vegetarians, " the only doubtful exception to this is based on a single observation of the male *Stegomyia fasciata* which was stated to bite man." It is stated that this is in all probability an error, because the anatomical arrangement of the mouth-part of this particular Stegomyia are opposed to the view that it sucks blood. One has personally on three occasions captured male Stegomyia, twice *S. calopus* and once S. *scutalaris* that had fed on oneself. The statement often put forward that male Stegomyia do not enter human dwellings is incorrect—one has seen numbers of them in houses in Delhi, Meerut and Fatehgarh in September.

It is certain that anophelines may breed in vast colonies 150 miles away from human beings. It is not necessary that the female should feed on either human or vertebrate blood before laying eggs—*A. maculipennis*, *A. bifurcatus*, and *C. pipiens*, who have been kept artificially without sucking blood, will deposit fertile ova. Mosquitoes breed mainly without the stimulus of human blood."—(THEOBALD).

Length of life of mosquitoes.—Formerly it was believed that mosquitoes lived only for five or six days. Now we know that they may live for months. *Stegomyia fasciata* can certainly live for five months. Anophelines have been kept alive in captivity for 155 days. There are many mosquitoes known to hybernate both as adults and as larvæ throughout the winter. We cannot at present say what the average length of the life of the mosquito in nature is. In captivity we remove them from the dangers of their natural enemies, birds, inclement weather, high winds, excessive rain, etc., although they must be affected by the artificial conditions of life in captivity.

Anophelines can certainly remain alive in huts for one or two months and possibly longer. Subsequent to the drying up of all their breeding places, it is found that the number of anophelines do not decrease to any material extent for several weeks, but if this drying up continues, their numbers gradually diminish; species may, however, be caught in the neighbourhood for two months (or even more) afterwards.

Generally, in captivity mosquitoes after a time become weak and are often seen to fall into the water when depositing eggs. They find difficulty in hanging on to smooth glass. Even when a rough surface is provided, they are repeatedly found at the bottom of the cage resting horizontally. After depositing eggs they usually die the same night.

In very hot parts of India during summer anophelines which remain through the very dry summer appear to show some peculiarities in their "habits":—

(1) "They feed regularly and are found full of blood," thus contrasting with hybernating mosquitoes.

(2) The ovaries are in the majority large and the ova fully developed.

(3) They do not lay their eggs even when test pools are made near the houses in which they abound." *

In the hot season as a rule only few breeding grounds are to be found, and "these do not represent the distribution of anophelines in the area in question" at this time and under these circumstances.

Fecundation of mosquitoes.—In nature this occurs soon after escape of the imago from its pupal case. It is, in fact, seldom that an unimpregnated female is found. Pairing occurs in the sunshine. Union of the sexes may also occur in captivity when bred out from larvæ and placed in test tubes. Eggs have been laid by females that have never paired in captivity, but such eggs do not yield larvæ.

Rate of multiplication of mosquitoes.—Mosquitoes are very rapid breeders. All the species of anophelines known in this country pass through several generations during the period from the commencement of the rains to the setting in of the cold weather. It has recently been calculated by FICALBI that from a mother stem two hundred millions of mosquitoes may be produced in four months.† During the breeding season each succeeding generation of mosquitoes becomes considerably larger in numbers than the preceding one, and when we consider the

* STEPHENS and CHRISTOPHERS, *Practical Study of Malaria*, 3rd Ed., p. 18.

† *Journal of Tropical Medicine*, 15th May 1909, p. 27.

rapidity of their multiplication and that this is in geometrical progression, there is obviously an enormous advantage gained in lessening the number of generations.

Local irritation from mosquito bites.—The irritation caused by a mosquito bite has nothing to do with malaria. The irritation is caused by the fluid injected by the mosquito from the diverticula which contains enzymes of bacteria ; this causes congestion of the part and thus admits of a full supply of food to the surface. The first thing the mosquito does is to insert its proboscis into the skin ; the next is to project this poison, which she does before drawing blood. Persons living in mosquito-ridden places acquire an immunity to this poison, which does not in them produce any irritation, just as some men in this country who are constantly gathering honeycombs from jungles become immune to the stings of bees. It is well known that some people possess a natural immunity to this poison. The absence of irritation is therefore not a sign of exemption from malarial infection—it may disguise the fact when malarial infection has occurred. We also know that the bite of malaria-bearing anophelines is associated with less discomfort, pain, and annoyance, than that of either of the other two chief genera of mosquitoes in this country—Culex and Stegomyia. The irritation caused is less in inhabitants of mosquito places. This, as above stated, is possibly explained by an immunisation against the bacterial enzymes injected from the diverticula acquired by residence in the area, and is of no importance in the etiological study of malaria.

The characteristics of the sub-families of mosquitoes are fairly well defined and, on the whole, the same may be said about the genera, though from the fact that new species are being constantly discovered all over the world, it may be said that our present classification will in the future undergo some modification.

In the study of mosquitoes in relation to malaria, we are concerned with only two sub-families—*Anophelina* and *Culicina*. The latter is important to us only in so far as it helps us to study avian malaria, which in many particulars is similar to human malaria.

Before proceeding to a detailed consideration of the more important Indian *Anophelinæ*, it may be useful to make a few remarks regarding the two genera Culex and Stegomyia, which are so extensively represented in this country.

Genus *Culex*, Linnæus—Normally have narrow curved median head scales, and similar ones on the scutellum. Upright, forked and narrow curved scales on the head, which has also lateral flat scales and elongated side scales on the wing veins. Male palpi are pointed. The type species is *C. pipiens*, Linn., the common gnat of Europe, and in this country, the *C. fatigans*, Weid.

***Culex fatigans*, Weid.**—It is essentially a domestic mosquito and is not a strong flier. They bite at night, especially indoors. In most districts they bite viciously, but in some they do not bite at all.

The thorax is covered with narrow curved, golden, brown scales; abdomen has basal pale bands to the segments; the legs and proboscis are unbanded. The stem of the first marginal cell is always less than one-fifth the length of the cell.

It is the commonest mosquito of this country. It can be told by the first submarginal cell being immensely long. It transmits filiariasis to man, and, in India, is the common carrier of Proteosoma and Halteridium of birds. It is met throughout the tropics 40° N. and S. of the Equator, having a similar range to Stegomyia.

Ova of *Culex fatigans*.—The eggs occur as an irregular raft-shaped mass on the surface of water; the raft is often shaped like a pointed ellipse, convex below, concave above; all the eggs are standing on end closely applied side by side in from 6 to 13 longitudinal rows, with 3 or 4 to 40 eggs in a row. Each raft consists of from 200 to 400 eggs. The individual eggs are 0·7 mm. long and 0·16 mm. in diameter at the base. The egg mass is about one quarter of an inch long. The eggs are first deposited after the commencement of the rains. At the beginning of the rains they hatch out in from 16 to 24 hours. They often issue from the under side of the egg mass and are very active. They frequently come to the surface to breathe, and during the first few hours of life may be seen under the shell of the raft getting air from the air film by which the mass is surrounded.

Larvæ of *Culex fatigans*.—The mouth of the larva is provided with tufts which are constantly v brating.

The head is large, antennæ long, thorax swollen, abdomen slender, the sides of the body are provided with bristles. The siphon tube is long and springs from the dorsal surface of the 8th abdominal segment, and this tube is thrust through the surface film of water when the larva rises to breathe. The extremity of this tube is provided with a spiracle and into it run the two main tracheæ of the body. The true end of the body is provided with four flat flaps. The specific gravity is slightly higher than water, but the difference is so small that the tension of the surface film of the water is sufficient to maintain it without exertion while breathing.

Genus *Stegomyia*.—The species of this genus are easily diagnosed by the head and scutellum being entirely clothed with broad flat scales. The scales on the clyheus of Stegomyia separate the genus from all others in which it is nude. They are mostly black and white mosquitoes and from the striped or banded character of the legs are called in this country the "tiger mosquito."

***Stegomyia calopus* (*S. fasciata*, *Meigen*)**, exists over a belt round the world extending to 38° N. and S. of the Equator. It is universal in India. It is rather small and breeds continuously all the year round in certain parts of India. It is a handsome insect, dark in colour, with silvery white bands on the legs, conspicuous silvery stripes on thorax, silvery bands on palpi, silvery spots on the side of the thorax and abdomen. Its chief character is its ornamental thorax which has a curved silvery line on each side and two dull yellow parallel lines in the middle. In some specimens these central lines are absent. It is an active biter both by day and night. It is the carrier of yellow fever. In the natural condition it breeds in fresh water, but in and around towns, villages and houses, will breed in any artificial collection of water, such as barrels, puddles, cisterns, tins, broken bottles, etc. It is domestic, seldom seen far from human habitations. They are, however, also forest dwellers. It is a long lived mosquito. GUITERAS has kept them alive for 150 days, and in the dry season with no opportunity to lay eggs this is said to be a common period of longevity. Its length of flight is not known definitely, but it has been found on board a ship a mile from shore, the vessel having come from a non-mosquito country. All Stegomyia when resting on a dark background, such as a black coat or dress, presents a peculiarly striking appearance ; the white bands on the legs at once distinguish it from *Culex* and *Anophelinæ*. They can usually be diagnosed as such on the wing.

Stegomyia *eggs* are deposited singly, each on its side, preferably in artificial collections of water, such as cisterns, fire buckets and tubs. The eggs are found singly or in groups forming parallel or geometrical figures; they are black in colour, cylindrical in shape, with conical ends, one blunter than the other, 0·6 mm. long and 0·16 broad. They deposit from about 35 to 110 eggs at a time, the average being 50. They are very hardy and withstand dessication. They have been thoroughly dried for three months and then hatched in water (TAYLOR). They hatch after deposit in water from 12 hours to three days, depending on the temperature of the water.

Larvæ of *Stegomyia calopus*—The *larvæ* are like those of *C. fatigans* but more slender; the respiratory tube is stumpy, short, and swollen in the middle like an olive ; growth is very rapid, the minimum period of development being six days. They seem to develop rapidly in foul stagnant water. Any place in which rain water has collected may contain them.

The *pupa* is rather dark in colour ; it has a longer abdomen and shorter thorax than *C. fatigans*; its minimum period of developmeut to imago is two days.

Steg. scutellaris, **Walker**—is a vicious biter, very common in this country, especially inland. The thorax has only one median silvery stripe by which it is distinguished from the unusually ornamental thorax of *S. calopus*.

Stegomyia larvæ are chiefly found in artificial collections of water, but they also occur in natural pools. *Stegomyia calopus* selects small collections such as tubs, pots, jars, tanks, ponds, cisterns, ditches, etc. Culex are found in all kinds of places such as drains, refuse waters, fire buckets, etc. They feed on all kinds of minute organisms floating in water or resting on the bottom of their breeding grounds.

To comprehend the present day prophylactic measures against malaria it is necessary to know something about methods of classification, and the identification of *Anophelina* from other sub-families of mosquitoes; we have already considered the general characters of the Culicidæ and roughly considered the Culicinæ, it is now only necessary to deal with Indian *Anophelinæ*.

General characters of Anophelinæ.—*Anophelinæ* may be told from other mosquitoes by the combined characters of the long palpi in both sexes, absence of flat thoracic and scutellar scales, and their straight proboscis. Almost all have spotted wings, and when at rest are at an angle to the resting surface, the head, thorax and abdomen being in one line. The larvæ of anophelines have no siphon tubes, and in the water rest parallel with the surface. Anophelines at rest, with few exceptions, may be recognised by its general resemblance to a thorn stuck in the surface of what it is resting on, the proboscis and body being much in one line, whilst in culicines there is an angle formed between proboscis, head, thorax and the abdomen, giving them a hunchbacked appearance; in both, the hind legs are free from the resting surface. It should be remembered that *Myzomyia culicifacies*, a general malaria-carrier in India, rests flat like a Culex.

There are 18 genera in the sub-family *Anophelina*, but we are only specially concerned with 8 of these genera—Anopheles, Myzomyia, Stethomyia, Pyretophorus, Myzorhynchus, Nyssorhynchus, Cellia, and Neocellia.

The primary characters by which the genera of *Anophelinæ* are recognised are the arrangement and shape of the hairs on the thorax and abdomen.

SUB-FAMILY ANOPHELINÆ.

Genus *Anopheles*, Meigen.

Contains a few large species met with on the hills in India. One has recently bred out a new species of this genus from the Tons river in Dehra Dun It has not as yet been described. The type species are *A. maculipennis* and *A. bifurcatus*, both of which are malaria-carriers in Europe. The true *Anopheles* only occur in Europe, North America, North Africa, on some of the Himalayan mountains in India and in Queensland, Australia.

They are diagnosed by the hair-like curved scales on the thorax and abdomen and by the wings being rather densely scaled with lanceolate scales.

Anopheles :—Indian species—*gigas, lindesayii, aitkenii, immaculatus.* Personally I believe this genus is more widely represented in India than is generally supposed.

Genus *Myzomyia*, Blanchard.

This genus is almost universally represented in India. The type in this country is *M. listoni*. They are structurally like *Anopheles* but differ in appearance—usually a few narrow curved thoracic scales projecting over the head, whilst wing scales are much smaller in proportion, but are long and narrow, and slightly lanceolate, the wings are more uniformly spotted, and always so along the costæ.

Myzomyia :—Indian species—*listoni, culicifacies, turkhudi.*

Myz. listoni and *Myz. culicifacies* are malaria-carriers.

Genus *Stethomyia*.

In addition to upright forked scales present on the head of all anophelines, there are some flat scales on the median area of the head. Wing scales lanceolote in shape.

Stethomyia :—Indian species—*culiciformis.*

Genus *Pyretophorus*, Blanchard.

Whilst the type species is the *P. costalis* of West Africa (an undoubted malaria-carrier), the type is represented almost throughout India. The genus is diagnosed by narrow curved thoracic scales and hairy abdomen ; the wings are much spotted. There are no scales on the abdomen.

Pyretophorus :—Indian species—*negrifasciatus, jeyporiensis, elegans.* *P. jeyporiensis* is probably a carrier of malaria, though this has not been proved by the finding of sporozoites in the salivary glands.

Genus *Myzorhynchus*, Blanchard.

This is a very characteristic genus of large, dark, densely scaled species, found in Asia, Africa, Europe and Australia. The thorax with hair-like curved scales, abdomen with ventral and apical scales, and a median ventral apical tuft, and with very densely scaled palpi in the female, and densely scaled proboscis.

Myzorhynchus :—Indian species—*barbirostris, nigerrimus.*

GENUS *Nyssorhynchus*, Blanchard.

This is a genus of closely allied species fonnd in this country (also in Africa and Anstralia). It appears to be an essentially Indian mosqnito—7 of the 12 known species are met with in this conntry and *Nyss. maculipalpis*, Giles, is common to India and Africa. The thorax is covered with narrow cnrved spindle-shaped scales, the abdomen with small flat or narrow curved dorsal scales in tufts (a few tufts projecting laterally), especially on the apical segments or in patches; the legs are always banded or spotted with white, and the tarsi have as a rnle one or more pnre white segments. This banding and spotting is of no generic valne. The palpi are thickly scaled.

This species shows considerable scale variations. The type is the *Nyss. maculatus*, Theobald.

Nyssorhynchus:—Indian species—*maculatus*, *stephensi*, *willmori*, *karwari*, *theobaldi*, *maculipalpis*, *jamesi*, *fuliginosus*. *Both N. stephensi* and *N. fuliginosus* are carriers of malaria.

GENUS *Cellia*.

A very characteristic genns. Flat spindle-shaped scales on thorax. The abdomen is nearly completely covered with scales disposed irregnlarly on the dorsum, and dense *tufts* projecting *laterally;* palpi and wings densely scaled.

Indian species—*pulcherrima*, *punctulata*.

GENUS *Neocellia*.

Flat spindle-shaped scales on thorax; the abdominal scales being as in *Cellia* but without the lateral tnfts. The species are classified by THEOBALD as follows:—

A. Last hind tarsi white.

B. Palpi apex black.

1. *N. indica*—Debra Dun.

BB. Palpi apex white.

2. *N. dudgeonii*. Resembles *N. willmori*, but has not apical and basal banding of tarsi to fore and mid-legs, is non-spotted in natnre, no white on first tarsi, thorax not dark brown. Head scales black and white, not all white. Fonnd in the Kangra Valley.

AA. Last hind tarsi not white.

3. *N. intermedia.* Femora and tibiæ yellow spots, costa six black spots. Palpi apex black. Deesa.*

The distinctions between the species of anophelines known to be malaria-carriers and those that are doubtful carriers in India are based upon the markings on the wings, legs, and palpi, these markings being caused by patches of light and dark scales The species can be distinguished by the use of the following tables† :—

M. listoni (Liston)	Wings spotted. *The third longitudinal vein is white scaled in almost its whole length.* Legs black with no trace of banding. Palpi with three white bands, the outermost of which includes the tips. Natural carrier of malaria.
M. culicifacies (Giles) ...	Wings spotted. *The third longitudinal vein is black scaled in its whole length.* Legs black with a few light scales at the tibio-metatarsal joints. Palpi with three yellow bands. Natural carrier of malaria.
M. turkhudi (Liston) ...	A large brown mosquito quite different in appearance from the above. The palpi have three white bands, but the tips of the palpi are black. There are light scales at the distal extremities of the femora and tibiæ in all the legs, and the hind femora have a broad pale area in the middle third of their length.
P. jeyporiensis (James) ...	Palpi with three white bands. Tips white. Legs black with minute bands at the tarsal joints. It is a small dark mosquito like listoni and culicifacies. [Is probably a natural carrier of malaria. P. H.]

* Stephens and Christophers, *Practical Study of Malaria*, 3rd Ed., p. 176.

† Copied from Major S. P. James', I.M.S., *Malarial Fevers*, 3rd Ed., p. 34, *et seq.*

Palpi with three white bands, one or more of the hind tarsal segments are pure white.

N. maculatus (Theobald) ...	Only the 5th hind tarsal segment is white.
N. willmori (James) ...	Only the 5th hind tarsal segment is white, but differs from *maculatus* in having the abdomen thickly scaled.
N. fuliginosus (Giles) ...	The 3rd, 4th and 5th hind tarsal segments are white. Legs not speckled. Natural carrier of speckled.
N. jamesi (Theobald) ...	Like *fuliginosus*, but the legs are malaria.
N. maculipalpis (Giles) ...	Like *fuliginosus*, but the legs and palpi are speckled.
N. theobaldi (Giles) ...	Only the 4th and 5th hind tarsal segments are white. Legs speckled.
N. stephensi (James and Liston).	The legs are speckled. Tarsal joints banded, but none of the hind tarsal segments pure white. Natural carrier of malaria.
Ps. rossi	Palpi with three white bands; wings have four spots and some basal spots. The second large spot has the characteristic T shape, but this varies. The tarsal joints are banded, but none of the hind tarsal segments are white. The legs are not speckled.

Rossi cannot be located amongst the eight Indian genera and it is found necessary to introduce a new genus for it, *viz.*, *Pseudomyzomyia*. This species is generally considered not to be a natural carrier of malaria although it has several times been made to do so artificially.

Ps. rossi is one of the commonest anophelines in India. It breeds in dirty pools, puddles and small collections of water, whereas *Myz. culicifacies* is not found in such pools, but occurs in fresh running water, small canals, tanks, superficial wells, etc. The inference frequently deduced from a malaria-bearing point of view is, that it is not necessary to primarily attack such puddles, and pools, whilst this permits of our concentrating our energies and available funds on the removal of the known habitats of ova and larvæ of malaria-bearing anophelines. One disagrees entirely with such a view—the larvæ of *Nys. fuliginosus* has been found in fairly foul rain-water puddles on several occasions; of *Nys. stephensi* in garden cisterns, and of *Myz. culicifacies* in small, foul, drying up pools.

One has not included *Ps. rossi* in the natural carriers, although one does not consider that we are as yet quite justified in excluding it from the malaria of India. We know that it carries experimental malaria, and that in some places in India where malaria is fairly severe it abounds, the known malaria-carriers being few. We have so far only record of about 1,200 or 1,400 dissections of *Ps. rossi* in which malarial parasites were absent from the midgut or salivary glands. These anophelines occur in myriads in some localities; because in a few hundred dissections in a station we do not find malaria parasites we are not quite justified in exculpating them. Were about 2,000 or so caught in the huts of infected persons found to be free from sporozoites and zygotes, it would be highly probable that they are not natural carriers in those huts. It is very probable that they are not carriers in the places where these dissections were conducted. They may be so in other places. So far, however, they have not been proved to be carriers.

"The attempt to ascertain the correct *genus* of an *Anopheline* is a task which the student of tropical medicine need not *necessarily* undertake, and those who decide to neglect the generic grouping of the *Anophelinæ* will be able to ascertain the correct specific name of any species which they may find in India by the use of the following table:—

TABLE OF THE INDIAN SPECIES OF ANOPHELINÆ.*

I.—Wings Unspotted.

A.—Palpi unbanded.

A. ailkeni (James) ... ... A small dark mosquito. No flat scales on head. Transverse veins of wings not in one line.

S. culiciformis (James and Liston) A rather large brown mosquito. A few flat scales on the median area of the head. Transverse wing veins in one line.

B.—Palpi with white bands.

A. immaculatus (Theobald).

II.—Wings Spotted.

A.—Palpi unbanded.

A. lindesayi (Giles) ... ... The wing has one large white spot near the apex. Femora of hind legs with a broad white band. Palpi not densely scaled.

* From Major S. P. James,' I.M.S., *Malarial Fevers*, p. 37, *et seq.*

A.—Palpi unbanded—(*contd.*)

M. barbirostris (Van der Wulp) ... A very large species with black densely scaled palpi. One white spot at distal end of wing.

M. gigas (Giles) ... ... A very large hill species. Costa of wing has two black spots.

B.—Palpi with four white bands.

M. nigerrimus (Giles) ... Tarsal joints banded, but none of the hind tarsal segments pure white.

C. pucherrima (Theobald) ... Abdomen covered with broad white scales. Legs speckled. The 3rd, 4th and 5th hind tarsal segments pure white.

C. punctulata (Donitz) ... Legs banded and speckled, but none of the hind tarsal segments pure white. Abdomen with white scales which form tufts at the sides.

Ne. intermedia (Rothwell) ... Like *punctulata*, but the abdominal scales are less dense and do not form tufts at the sides.

P. elegans (James) ... ... Like *punctulata*, but no scales on abdomen.

N. karwari (James) ... ... Legs not speckled, but with bands at the joints. The 5th tarsal segment of hind legs pure white.

C.—Palpi with three white bands.

I.—Tips of palpi black.

M. turkhudi (Liston) ... None of the hind tarsal segments white. Thorax with hair-like scales.

P. nigrifasciatus (Theobald) ... Like *turkhudi*, but the thorax has narrow curved scales.

Ne. indica (Theobald) ... Only the 5th hind tarsal segment is pure white. Abdomen with flat scales.

C.—Palpi with three white bands—(*contd.*)

II.—Tips of palpi white.

One or more of the hind tarsal segments are pure white.	*N. fuliginosus* (Giles)	Tarsal joints banded; legs not speckled. The 3rd, 4th and 5th hind tarsal segments pure white.
	N. jamesi (Theobald)	As above, but with speckled legs.
	N. maculipalpis (Giles)	As above, but with legs and palpi speckled.
	N. theobaldi (Giles)...	Only the 4th and 5th hind tarsal segments are pure white.
	N. maculatus (Theobald).	Only the 5th hind tarsal segment is pure white.
	N. willmori (James)...	Differs from *maculatus* in having many scales on the abdomen.
	N. dudgeoni (Theobald).	Very like *willmori*.
Tarsal joints banded, but none of the hind tarsal segments pure white.	*Ps. rossi* (Giles) ...	The legs are not speckled.
	N. stephensi (Liston and James).	The legs are speckled. Abdomen covered with scales.
Legs uniformly coloured without bands or white segments.	*M. listoni* (Liston) ...	The third longitudinal vein of wing white scaled. Six white patches on wing fringe.
	M. jeyporiensis (James)	Seven white patches on wing fringe. Faint white spots at some of the joints of the legs.
	M. culicifacies (Giles)	Third longitudinal vein of wing black scaled. Faint white spots at some of the joints of the legs.

The following examples will serve to illustrate the method of using this table :—

" *Example I.*—A female mosquito with palpi as long as the proboscis, *i.e.*, it belongs to the sub-family *Anophelinæ.*

Wings.—Spotted.

Palpi.—With three white bands or rings, one broad ring including the tips (which are therefore white), and two narrower ones.

It therefore comes among the spotted winged *Anophelines* under the group C, sub-group **II.**

Legs.—There are white bands at the tarsal joints, but none of the hind tarsal segments are pure white, and there is no speckling of the legs in addition to the bands.

Diagnosis—*rossi.*

Confirm by careful examination of the wing markings.

" *Example* 2.—A female *Anopheline.*

Wings.—Spotted.

Palpi.—With three white rings, the outermost of which includes the tips. In addition to the three complete rings there are one or two small patches of white scales, which do not amount to a complete ring or band, on the upper surface of each palp, *i.e.*, the palpi are marked with three bands and are speckled in addition.

Legs.—The 3rd, 4th, 5th, and the apex of the 2nd tarsal segments of the hind legs are pure white. There are white bands at the other tarsal joints, and the femora and tibiæ are brilliantly speckled with white scales.

Diagnosis—*maculipalpis.*

" *Example* 3.—A female *Anopheline.*

Wings.—Spotted.

Palpi.—With three white rings and the tips white.

Legs.—Uniformly coloured without definite bands at the tarsal joints.

Diagnosis—*listoni,*
jeyporiensis, or
culicifacies.

Separate by careful examination of the wing markings."

This table may with confidence be accepted as a simple guide to the identification of the known species of Indian *Anophelinæ.*

EXAMINATION OF ANTOMICAL STRUCTURES OF ANOPHELINES.

The first step is to be quite sure that we recognise anophelines when we see them.

Examination of proboscis, palpi, and antennæ, at once gives the sex and whether the insect is an anopheline or not. In the anopheline the proboscis is straight and the palpi are as long, or nearly as long, as the proboscis.

Head.—Note the character of the scales, especially the upright forked scales.

"In most anophelines a prominent tuft of white hair projecting forward from the anterior of the head will be seen."—(S. P. JAMES).

The palpi.—The banding of the palpi by white scales is most useful in recognising species. The apices of the palpi are generally white, but they are dark in *Myz. turkhudi*, and *Nyss. theobaldi*, var. *nagpurensis*. The number of bands on the palpi, their width and distance apart, whether the two apical ones are of equal width to the other palpal bands, etc., are of some significance. In this connection one should not forget the differences that occur in the same species from even the same batch of eggs, and that seasonal variations likewise occur. We look also for white scaled patches on the segments of the palpi—these are important.

Antennæ.—In examining *antennæ* note whether they are densely covered with scales or not, whether all of one colour, or adorned with white bands and the number of these latter, their position and relative size. In the *male* the *antennæ* are covered with long hairs, the antennæ having a plumose appearance in front of the head. This can be seen with the naked eye. In the female the antennæ are almost bare and in no mosquitoes found in this country have they long hairs. The adult female may also be recognised when the abdominal cavity is distended with eggs or is full of blood recently sucked.

Thorax.—The dorsum is covered with scales or hairs or with both; the character of these scales is to be noted.

Scutellum.—The *scutellum* is always simple in anophelines and *never tri-lobed* as is the case in all other *Culicidæ*. It is provided with hairs or scales.

The **Post-scutellum** *or metanotum.*—This is bare.

Halteres.—The knobs of the *halteres* or balancers are covered with many small scales.

Abdomen.—This region is very important. In some species there are very long hairs, but no scales. In other species in addition to hairs a few scales are seen on the ventral surface of the last one or two segments only. In others again the dorsum of each segment is thickly set with white or golden brown scales which in some species are very broad and in others more or less spindle-shaped.—(S. P. JAMES.)

Several of the species of Nyssorhynchus can readily be diagnosed by the number of white tarsal bands, which may vary from 1 to 3 and a fraction of the next segment. The femora and tibiæ may be speckled or unspeckled. The two species of *Cellia* met with in India may be recognised by examining the tarsi of the hind legs apart from the four white bands on the palpi.

Ungues are sharp pointed horny structures fixed to the tip of the fifth tarsal segment of each leg.

Wings.—We note the relation and position of the different dark and light scaled areas on each vein. The chief spots consist of groups of scales on the costal, sub-costal, and first longitudinal veins. These spots are sometimes arranged in a characteristic manner as seen in the "T spot" of *Ps. rossi*. In all species variations are met with in these spots, and minor differences are insufficient to form a new variety and scarcely ever so to give rise to a new species This is constantly seen in the imagines of anophelines bred out of the same batch of ova. Nevertheless the number and grouping of the spots are of some importance in diagnosing species.

The small areas of scales found on the third to the sixth longitudinal vein are of use, and in describing an anopheline wing the arrangement of these areas should be given. The degree to which the third long vein is scaled is also of special significance. A complete description of a wing should include all the minute spots on the wing.

The wing fringe possesses at the points where the long veins intersect the margins a variable number of pale areas. The shape of the wing scales is to be noted by examination of a wing under a cover glass.

The legs.—The legs of anophelines are longer and thinner than those of other mosquitoes. Like those of other mosquitoes the legs consist of (1) *Coxa* and trochanter, which are small structures at the beginning of the legs; (2) femur; (3) tibia; (4) tarsus, which consists of five segments, the fifth carrying the *claws* or *ungues*. "It is necessary to make a careful examination of the markings on each leg beginning with those on the femur and ending with those on the fifth tarsal segment." The various tarsal segments may be banded or speckled and the banding may be apical or basal on the tarsal segments. In some species complete bands of white scales encircle the legs near the joints, and the position of these bands should be noted.

In addition small patches of white scales will be found in some species on certain segments of the legs (*speckling*), and in some species one or more of the terminal tarsal segments of the legs will be found to be white scaled in their whole length.

Other points of comparative insignificance are the position of the cross veins on the wings, characters of the ungues and genitalia in the male.

The most satisfactory way of acquiring a familiarity with the different species of anophelines in a locality is that of breeding them from ova and larvæ.

Some of the known species of Indian anophelines can be at once recognised by examining the wing, the bandings on the legs, and bands on the palpi, but a hurried examination of the wings and legs may not only lead to error but to the non-recognition of new species.

In describing an anopheline the position, number, and dimensions of the pale bands (if any) on the palpi and on all the last tarsal joints, any adornments in the shape of white lines or groups of white or coloured scales on the body, and the markings on the costal borders of the wings in the shape of groups of white scales, should be given. Anophelines are often called the "spangled" or spotted winged mosquito, and "marsh or swamp mosqnito," both of which are not altogether correct descriptions, as there are anophelines without spots on the wings, and anopheliues breed in other places besides swamps; nevertheless these appellations show two of their commonest peculiarities. All anophelines that carry malaria in Iudia have spotted wings and most anophelines prefer breeding in swamps.

The number of species of anophelines in any particular place under investigation is fortunately small, and the difficulties of identification therefore easily overcome. The maximum number of anophelines found by me in any one station was eight; six of these eight were bred out from the Tons and Nun rivers in Dehra Dun between the 11th and 16th October 1909. The number of species in each of the genera of Indian Anophelinæ is also small, so that if the geuera is recognised the distinction of the species with the aid of the table quoted is comparatively easy. With this table it is not necessary to trouble oneself about the genus.

Anopheline larvæ.—In early life anopheline larvæ normally remain on the surface, and even when of moderate size seldom go to the bottom. When moving on the surface they wriggle backwards The body is held parallel with the surface and just below the surface film so that a part of the head and the two breathing orifices on the eighth abdominal segment are out of the water. The head rotates on the neck so that the larva can turn it round with the greatest of ease, and it habitually feeds with the under surface of the head towards the surface of the water. The long fringes of the mouth, "the feeding brushes," are constantly vibrating and causing inward currents towards the mouth, so that all particles in the neighbourhood are drawn towards the mouth at a rapid rate—spores of algæ, confervæ, and tiny particles of all kinds are thus taken into the digestive tact, and under a low power lens may be seen in the living larvæ passing though the head into the thorax.

The specific gravity is nearly equal to that of water—the tension of the surface film affords all the support it requires to enable it to float.

The general structure of anopheline larvæ is peculiar and at once distinguishes them from other sub-families. The head is small, there is no projecting respiratory tube or syphon, the body is provided with long lateral branching hairs and upon the dorsal surface of a varying number of abdominal segments, there is a pair of palmate hairs, each with a stalk and a conical bundle of fine hairs, the whole forming a little fan-shaped structure. It is by means of these palmatic hairs, which cling to the surface film, that the larva retains its horizontal position just under the surface. The numbers of pairs of palmate hairs and the segments on which they are placed are important in distinguishing the species to which they belong. The characters of the individual leaflets and their terminal filaments are also of specific importance. The ninth abdominal segment bears below a fan-shaped arrangement of long hairs.

The neck of anopheline larva is very slender and the head can be turned upon the body. This is because the larva finds its food on the surface, and gathers it by the constant motion of little broom-like processes projecting from the sides of the mouth, and furnished for this purpose. The breathing tubes project slightly from the upper surface of the eighth abdominal segment. To get its mouth to the surface, while maintaining its position for breathing, requires that the head should be turned half round on the body, which position is impossible to larvæ of other sub-families of mosquitoes. The larva becomes a pupa in about 10 to 12 days. In from two to four days or more the pupa becomes an imago or full-grown anopheline. All mosquito larvæ are popularly called "wrigglers" or "waggle-tails." As there are few larvæ or pupæ that can stand frost it is probable that in the extreme cold of Northern India the species are maintained through fecundated hibernating adults.

A word-description of the various anopheline larvæ that may be met with in India would serve no useful purpose to those unfamiliar with the characters of such larvæ; a few days' practical experience in collecting and examination of larva overcome the initial difficulties. They have certain naked eye characters which in a general way tell us what they are likely to be, but for identification the microscope is necessary. They should be first examined with a $\frac{2}{3}''$ objective and, if necessary, subsequently with a $\frac{1}{6}''$ lens.

The more important characters of the larvæ of the four malaria-bearing anophelines are as follows:—

Myz. culicifacies larva.—The median and frontal hairs are simple and unbranched; pairs of palmate hairs on the thorax and from the first to the seventh abdominal segment inclusive, the terminal filament of each is long and thin; the head pattern is not very characteristic.

Myz. listoni larva.—The frontal hairs are simple and unbranched; palmate hairs on all the abdominal segments from the first to the seventh, and a well-developed pair on the thorax, the terminal filament in each being moderately long; the head pattern may be quite characteristic.

Nys. fuliginosus larva.—The median frontal hairs are slightly branched; branching of the external frontal hairs is well marked; the antennæ are devoid of branching hairs; the palmate hairs extend from the first to the seventh abdominal segment, and there is no pair of palmate hair on the thorax; the terminal filament of the leaflets is long and attenuated.

Nys. stephensi larva.—Both frontal hairs are slightly branched; palmate hairs are found from the second to the seventh abdominal segments; an undeveloped pair of palmate hairs is very occasionally found on the first abdominal segment and thorax; the filaments of the leaflets are comparatively short and blunt; the antennæ possess a single small unbranched hair; the head pattern is not characteristic.

Pyr. jeyporiensis is also probably a malaria-carrier.

Pyr. jeyporiensis larva.—The median and external frontal hairs show short but well marked lateral branches; palmate hairs are found on all the abdominal segm-nts from the first to the seventh, as well as a pair on the thorax; the head pattern may be fairly distinct.

The most commonly seen anopheline larva is that of *Pseudomyz. rossi*, in which both the median and external frontal hairs are simple and unbranched; palmate hairs are found on from the second to the seventh abdominal segments and rarely on the first abdominal segment, and then only poorly developed; the terminal filament of each leaflet is very long and attenuated and the head pattern is often characteristic.

The head patterns ordinarily depicted are those generally met with, but they vary very much and cannot be relied on for identification. The frontal hairs and antennæ are the most reliable structures to depend on. The palmate hairs also vary a little; *e.g.*, both *Ps. rossi* and *Nys. stephensi* larva may have well developed palmate hairs on the first abdominal segment, and very occasionally rudimentary ones in the thorax. The colour of larvæ is of no use for identification, it depends on the nature of the food consumed. One has seen *Ps. rossi* larva of a vermilion red, dark green, and light yellow—the head always being black.

Larvæ may be examined under a low power on a slide with or without a cover glass; a cover glass keeps them from wriggling about. The chief structures to which attention should be directed are—the antennæ, clypeal or frontal hairs, leaflets of the palmate hairs and their terminal filaments, and the segments which carry palmate hairs. These are all of specific importance.

The Nympha.—The stage between the larva and imago lasts about 48 hours. When the larva has cast its larval coat the nymph is light in colour and difficult to see. Later it becomes darker, and towards the end and immediately prior to emergence of the imago, *silvery patches* due to collections of air are seen beneath the cuticle.

The cycle of development from egg to imago in *Ps. rossi* and *M. culicifacies* is 14 days, and in most other Indian anophelines probably about the same.

They are found chiefly in terrestrial waters, especially where there are water weeds or grass. The margins of rivers, lakes, pools, ponds, where weeds and grass are found, form favonrite spots. They have a special *penchant* for small weakly flowing streamlets where there is an absence of their natural enemies, such as minnows, etc. Runnels of water, water-courses blocked with vegetation, pools, little collections of rain-water on grass, borrow-pits parallel with both sides of railway lines, roadways, and canal embankments, pits used for watering gardens, artificially made collections of water for adorning private and public gardens, excavations in rocks, etc., may all contain them. They thus differ from larvæ of Culex and Stegomyia which prefer small collections of water in the immediate neighbourhood of houses. Anopheline larvæ prefer marshes or collections of water comparable with marshes. Hence marshes are commonly associated with malaria from which arose the names of *palludism*, *marsh* fever. Anophelines are in some places known as *marsh mosquitoes*.

When water contains weeds it is difficult to recognise the different kinds of larva by the naked eye. In all such cases a "dipper" is essentially necessary. The best kind is an iron mug lined with white enamel and having a handle.

Water weeds form favourite cover under which anophelines hide from their natural enemies. Hence pools and shallow lakes containing weeds, which to the naked eye show no larvæ, are often stocked full of them.

Species that carry malaria.—It is popularly thought that all *Anophelinæ* are malaria-carriers. We have no proof that this is so and we have proof that some of them are not carriers. Up to the present of the 27 species known in India, only four species are known to be natural malaria-carriers in India—*Myzomyia listoni* (Liston), *Nyss. culicifacies* (Giles), *Nyss. fuliginosus* (Giles), and *Nyss. stephensi* (Liston)—and hence inquiries regarding these and their breeding grounds in a malaria district is most important. *Pyr. jeyporiensis* is probably a natural carrier also. The frequency with which one has met both winged and larval *Nys. stephensi*, led one to write for information regarding it to various experts on malaria in India. Last year Captain GLEN LISTON, I.M.S., demonstrated that it was a carrier of malaria in Bombay. Dr. C. A. Bentley, Health Officer, Bombay, has dissected several hundred specimens caught in various parts of Bombay since June 1909, and found that 14 per cent. of those dissected showed zygotes in the midgut, and about 5 per cent. in the salivary glands. Dr. Bentley states that *Nys. stephensi* is the most important carrier of malaria in Bombay.*

It is generally stated that one infected anopheline may, during its comparatively short lifetime, infect several persons and thus disseminate malaria. The records of recent expermients tend to show that there is a limit to their infectivity in captivity; but at the present time it is not possible to state how many persons may be infected naturally by one mosquito in nature. One has certainly found young zygotes in the stomach wall at the same time that sporozoites were in the salivary glands, showing that there probably had been more than one infection of the insect. This is not necessarily the case, however, as it has been shown that when malaria-carrying anophelines bred out and infected by a single feed on malarial blood, it has been found that the stages of the development of the zygotes in the stomach walls differ.

Malarial infection cannot of course arise from the bite of anophelines unless the latter have fully developed sporozoites in their salivary glands. The anophelines must themselves have been infected from men with some form of malarial fever at least a week before, and the atmospheric temperature and other conditions must be suitable. Further the sexual forms in the human blood must be fully developed at the time of the bite and ready for conjugation to infect anophelines.

Flight of anophelines.—The flight of anophelines—the most delicate of the *Culicidæ*—is limited. This flight is said to be generally limited to half a mile. This being so, the extermination of all breeding places within an area of half a mile radius should eliminate malaria. Immigration of mosquitoes from other areas into cantonments and places where anti-malarial operations continue has been urged against such measures There is evidence to show that such importation in endemic malarial areas is constantly in progress, but under normal circumstances immigration and emigration balance one another, so that this factor alone should not affect the question of anti-mosquito measures. In a recent investigation of the malaria in a large district one found both winged anophelines and their larvæ in every plains station within half a mile of cantonments, in most stations in the heart of the cantonments themselves.

It may be stated that up to the present time the distance anophelines can fly is a question that has not been definitely settled. The probability is that they seldom fly over half a mile, and they cannot fly even this distance if there are any barriers to penetrate, such as trees, jungle, etc. It is a mistake to cut down trees indiscriminately in the belief that they harbour mosquitoes. This may give anophelines an inlet from infected bazar or village huts, or from breeding grounds. On the other hand long grass, jungle and brushwood may foster anophelines by giving them rest and shelter between their breeding places and human habitations.

* I am indebted to Dr. C. A. Bentley, Health Officer, Bombay, for this information.

Breeding places of *Anophelinæ*.—It is found that one kind of anopheline will from many different kinds of collections of water choose a muddy and shallow collection, others will select streams or irrigation channels, others rice-fields, and others again will breed in deep clear ponds or lakes.

Species *breeding in open water with much aquatic vegetation* at some distance from houses, such as deep ponds, swamps, marshes, and deep pools under trees or in a wood :—

A. *barbirostris.*

A. *nigerrimus.*

My personal experience is that larvæ of both these two species are amongst the commonest larvæ in cantonments and in village ponds. They are most frequently found together and may occur in any natural collection of water. Specimens of the winged form of both were found in huts on two occasions recently.

Adults of these are rarely found in houses; they are essentially wild mosquitoes.

Stream breeding species.—The larvæ of these species are most frequently found in running streams. They include *Myz. listoni*, *Myz. culicifacies*, *Pyr. jeyporiensis*, and *Nys. maculatus.* Irrigation water-courses form the chief breeding places in the Punjab for one of the members of this group (*Myz. culicifacies*). Where such breeding places are common the adult insects of this group are abundant in houses.

"**Pool breeding species.**—The most important of this group is *Ps. rossi*, which is almost always found breeding in shallow muddy pools in the vicinity of houses. As would be expected from the nature of its breeding ground, this species is most widely distributed in India, and after the rains may be found in enormous numbers in houses. It is essentially a 'domestic' species."* When ordinary breeding places are absent anophelines may breed in any collection of available water, hence in all inquiries regarding malaria every collection of water should be carefully examined. Anophelines are, however, naturally selective in the collections of water they deposit their eggs in. The state of breeding grounds is of course largely influenced by the rainy season. Wherever in India suitable breeding grounds remain throughout the year, if the average temperature is not below 18° C. (46° F.), mosquitoes continue to breed, and there is in such places neither hibernation nor æstivation.

Anopheline larvæ have never been found by me in large irrigation canals and their branches when these were in pucca conduits free from grass and weed; they were, however, always found in katcha irrigation channels, and in the katcha waste channels from pucca irrigation canals.

* Major S. P. JAMES,' I.M.S., *Malarial Fevers*, pp. 43-44.

The absence of larvæ from pucca canals is explained by the periodical shutting off of the water or by the rapid flow in a channel usually devoid of grass and vegetation.

Anopheline larvæ are specially found under cover of grass and weeds and are not often seen in the open, except in stagnant waters. There are, in one's personal experience, three exceptions to this—*Ps. rossi* may be found in deep dirty pools in which buffaloes wallow, and in which there is an entire absence of grass or any other cover, and *Myz. barbirostris* and *Myz. nigirrimus* may very rarely be found in small and medium sized clear pools without grass or weeds.

The smaller and moderate sized collections of water are more favoured by anophelines for oviposition than the larger. Recently one found that a comparatively shallow pool connected with a hydrant in the Native Infantry Lines at Agra swarmed with *Myz. culicifacies* and *Ps. rossi* larvæ. The greatest masses of malaria-bearing larvæ have always been found in some moderate sized pools. It may be here remarked that of two similar tanks fairly adjacent to one another, for some unknown reason, one will contain many anopheline larvæ and the other none.

Sometimes a large tank may be searched around its whole circumference without finding a single anopheline larva, and then one reaches a small shallow branch of it or a small channel draining into it, which may contain myriads. The drying shallow parts are specially favoured by them. A very light wind, even one just sufficient to cause a barely visible ripple on the surface of the water, will often cause anopheline larva to drift to leeward. Time will often be saved by at once inspecting the leeward side of large collections of water.

One finds that whilst anopheline larvæ are often absent from deep collections of water, such as large tanks with perpendicular banks, they are almost always to be found in large numbers in shallow tanks, large and small, especially in the shallower parts of these tanks, and that their favourite breeding places are the small shallow pools around these tanks of from 5 to 30 feet in diameter, when these are provided with grass and weeds.

Capture of adult anophelines.—Adult mosquitoes when at rest may be captured in test tubes or small bottles by placing the mouths over them. Personally one has made more rapid captures by using small butterfly catching nets about 8 to 12 inches diameter, with a bamboo or cane circular rim at the top, and a short, 8 to 12 inch, handle. When required for simply counting relative numbers of different species of anophelines, or for dissection for sporozoite rate, this is a fairly rapid method of collecting anophelines. It is not to be employed when dealing with unknown species as it leads to much rubbing off of scales, and markings on wings, and may even lead to difficulty in identification of known species.

A simple and convenient method of catching anophelines, especially where they are few in number, is that of blackening the interior of packing cases provided with lids, each lid having a central hole to hold a cork. The cases are placed under beds in huts or in dark corners in the evening, with the lid resting on the ground. In the early morning the lid is rapidly closed; the cork is then removed, a little chloroform on cotton wool or blotting paper is inserted, the cork replaced. In a few minutes the night's capture will be found dead and may be removed and collected,* a lining of some black cotton stuff is preferable to simple blackening the inside of the boxes.

The captured anophelines may be put into an ordinary entomological bottle. Adult anophelines may also be bred out from larvæ.

The only accessories required in an anopheline chase are a small butterfly catching net, a large bottle with a wide mouth, test tubes and cotton wool.

Adult mosquitoes may be rapidly stiffled by tobacco smoke or by a few drops of chloroform in the bottle or test tube. If it is required to use these bottles and test tubes subsequently for living mosquitoes, they should be thoroughly washed out before use.

Out-houses, cow-sheds, unoccupied thatched houses with dirty soot-covered walls, are special day resorts for anophelines. Some favour the thatch beneath the eaves of huts and houses and require a ladder to reach them. Anophelines are rarely seen on whitewashed walls in the day time and not often at night. They may often be found in holes in walls, or in the corners of rooms, under beds and tables, in cupboards, on dark clothes in rooms; they are fond of hiding in old boots (Wellingtons and polo boots especially), on saddles—leather seems to attract them. We may see them at night wandering about the shady side of the mosquito net. In such shady places they are readily captured as they are probably asleep, and it is usually easy to place the butterfly net or mouth of the test tube quickly and quietly over them. The mosquito now flies into the body of the tube and a plug of cotton wool is applied to the mouth. These tubes should have blank labels pasted on them previously; or the required particulars can be written with a greased pencil.

The mosquitoes when captured in this way are put into the large bottle by placing the open mouth of the test tube into it, when the mosquito flies into it and the bottle is plugged again. In this way when anophelines are abundant, about 30 can be caught in an hour. One has known as many as 65 caught in an hour with test tubes, with assistants to transfer the mosquitoes to the large bottle, and as many as 110 with a butterfly net.

As stated above the captured mosquitoes may be killed by pouring a few drops of chloroform on the muslin cap of the large bottle, then dislodged on to a sheet of white paper, and, when necessary, mounted.

* I am indebted to Lieut.-Colonel F. Wyville Thomson, I.M.S., for this suggestion, *Journal of the Royal Army Medical Corps*, June 1909, p. 507, and H. Maxwell-Lefroy's *Indian Insect Pests*, p. 293.

In breeding out winged anophelines from larva, place 20 or 30 full grown larvæ or pupæ in the water in which they were found in a tumbler or finger bowl, and cover it with a piece of gauze supported on a framework of wire. In a few days the adults will be found on the gauze. A thin slice of banana may be put into the gauze to feed them. They should not be killed for a few days to allow them to develop—(GILES).

The most prolific sources for collection of different species are pools and eddies in river and stream beds, and katcha irrigation channels, when the edges are covered with grass or weed.

For mounting mosquitoes we require—fine silver pins (No. 20), pin forceps, discs of white cardboard, medium sized ordinary pins and box with a cork carpet in the bottom. "A card disc should be taken and one of the No. 20 silver pins thrust through its centres, so that about half of the pin projects each side. The mosquito to be mounted is turned over on its back and the part of the pin carrying the disc is entered into its thorax, at the point of origin of the legs, and made to emerge through the dorsum of the thorax. On turning the disc over the mosquito is mounted in its natural position, right side uppermost, and its legs and wings can then be gently arranged on the card disc with the aid of the pin. An ordinary pin is now thrust through the edge of the card disc to attach it to the cork at the bottom of the specimen box."*

When collecting mosquitoes for identification they should not be handled. A needle should be used for moving them about.

In examining mosquitoes for identification they should be mounted in the way just described and then a general inspection made with a hand lens. They should subsequently be put under a ⅔rd inch objective for detailed observation. The mosquito attached to its disc is removed and fixed on to a small flat piece of cork on the stage. The examination is of course through direct light. The pin can be fixed to the cork at any angle and the insect in this way moved about until all parts are brought into view. This is specially advisable when the different forms of scales have to be scrutinised.

Remarks on habits of winged anophelines.—It is necessary that special observations be carried on throughout the year, to determine the places of hibernation of larvæ, possible hibernation of adults, extent to which æstivation occurs, and the places on which anophelines obscure themselves in the very hot months of summer and during the cold of winter. It is possible that in some stations as Dehra Dun, Delhi, Muttra, Fatehgarh, etc., of the United Provinces, infection through anophelines occurs for one or two months during the late spring and early summer, if during March, April or May there happens to be a heavy fall of rain. This means that under this circumstance there may be two malarial seasons in such places, one which is short between during late spring or

* Major S. P. JAMES', I.M.S., *Malarial Fevers*, 3rd Ed., p. 27.

early summer, and the usual one during and after the rains. It is possible also that in stations where there are perennial breeding grounds, the occurrence of a heavy shower of rain during the period named is not necessary to bring about these late spring and early summer infections. I can give no evidence but that of the statistics before me, and the existence of potential breeding grounds of anophelines at those periods of the year in the stations referred to in support of this statement. The subject is here referred to as it is one of considerable importance in the epidemiology of malaria, and should not be difficult to prove or disprove in such stations as those mentioned, where potential breeding for malaria-bearing anophelines and cases of malarial infection, are always present.

Further observation from, say, the middle of March to the middle of May should elicit whether this is actually so, and whether the malaria-carrying species of anophelines disseminate malaria at that particular season. This could be ascertained by taking a sufficient number of anophelines in native huts at that time and determining the sporozoite rate.

It is most important that we should know the beginning and end of the season during which anophelines breed. There are some stations in which the winged malaria-carrier cannot be found after the 15th October, others in which it may be found at the end of October and well into November, and in a large number of stations in the Deccan and along the East and West Coasts of India, they may be found all the year round. In all stations in Northern India a certain number of anophelines continue on the wing and carry malarial infection for weeks, or even months, after the breeding season is over.

One has repeatedly watched the matutinal exodus of anophelines from houses, and on several occasions anophelines captured at this time contained either sporozoites in the salivary glands or zygotes in their midguts. The first effort made appears to be to rise to enter trees where these are in the vicinity. In the trees they are lost sight of.

Although only four anophelines have so far been proved to be natural carriers of malaria in this country, it would appear to be a sound general rule to consider all anophelines met with as potential carriers of malaria until they are proved not to be so. It is possible that under exceptional circumstances most anophelines may become malaria-carriers. Many species of anophelines have in this country been experimentally infected with human malaria, and it is probable that we have not yet ascertained all the species which in this country are natural carriers. The sub-family *Anophelina* is widely distributed in this country and this distribution in the main corresponds with the distribution of malarial fevers.

Distribution of *Anophelinæ* in India.—In 47 stations where identification of anophelines was attempted in 1907, the following species were found in the numbers of stations stated :—*Ps. rossi*, 36 ; *Myz. culicifacies*, 20 ; *Nys. stephensi*, 7 ; *Nys. fuliginosus*, 6 ; *Mr. nigerrimus*

5; *Myz. listoni*, 3; there were also found at different stations *Myz. maculatus*, *Mr. barbirostris*; *Nys. theobaldi*; *Nys. jamesi*, *A. lindsayi*.

In the 7th (Meerut) Division one found the following species of anophelines in the 9 plains stations during the breeding season :— *Ps. rossi* in every station; *Myz. culicifacies* in 8 of 9 stations; *Nys. fuliginosus* in 5; *Nys. stephensi* in 3; *Myz. listoni* in 2; *Mr. nigerrimus* in 2; *Myz. maculatus* in 2; *Mr. barbirostris*, *A. lindsayi*, *Nys. jamesi* and *Cel. pulcherrima* 1 in each station; and one unidentified species of *Anopheles* bred out of the Tons river in Dehra Dun.

Of the 7 hill stations in the 7th (Meerut) Division are found anophelines in only one station, Almora, in which there were a few *Mys. maculatus* and an unidentified species of *Nyssorhynchus*. In the same enquiry larvæ of all the species named except *Cel. pulcherrima*, *A. lindsayi* were found, *Ps. rossi*, *Myz. culicifacies*, *Mr. nigerrimus* and *Mr. barbirostris* predominating.

We have much to learn regarding the habits of anophelines before we can effect their eradication from even limited endemic malarial districts. Observations in such districts will have to be carried out for some years before we can solve many of the unknown problems of to-day that harass the anti-malarial sanitarian. One of the chief directions in which profitable study and observation might be carried on is in the method of æstivation and hibernation of anophelines. It is during these periods of hiding that their numbers are comparatively few, and were we to know where to attack them in the larval and adult stages during the non-breeding seasons, we would certainly materially diminish the numbers appearing during the breeding season. In places where that season continues all the year round the task is very difficult. Destruction of hibernating mosquitoes is most useful because if not carried out, being fecundated, the females will deposit their ova as soon as the meteorological and telluric conditions are favourable for her doing so. We can get some notion of the vastness of the problem before us when we consider the astonishing rapidity with which mosquitoes multiply—eight mosquitoes can from the beginning to the end of the breeding season create a race equal in number to the entire human population of the globe. Facalbi has recently put on record that a single mother can in a period of four months give rise to 200 millions of mosquitoes.

Hibernation of anophelines is considered to be carried out in the adult stage chiefly in out-houses, under bridges, sheltered parts of old ruins, on the under surface of shelves in walls, etc. They may sometimes be seen in masses on inner walls of neglected and empty out-houses.

In all countries where mosquitoes exist adults may be found at all seasons of the year, the species being maintained by the survival of fecundated females, who hide and remain quiescent during the periods that are unpropitious to the growth and development of larvæ. In the cold season they hibernate or hide in secluded and sheltered corners where they are not likely to be found by their enemies, often creeping into cracks and corners which appear too narrow for the admission of so delicate an insect. Those familiar with their haunts find living mosquitoes in India at all seasons.

When hibernating, mosquitoes are very sluggish, but except in very cold weather, they can still fly when capture is threatened. In India such hibernation is probably confined to the north. It is doubtful if anophelines hibernate anywhere south of Agra, and in Central India and the Deccan they are in evidence all the year round (GILES). Any warm day during the cold weather brings them out and a return of cold sends them back. A few months ago (Lansdowne, 5,500 feet, 28th November), while writing in a room in which a fire was burning (it was the first fire used this cold weather) one was surprised to find several *Stegomyia calopus* buzzing around, as they had not been seen in the station for over a month. The external atmospheric temperature was 49° F., and the temperature of the room at the time of the observation 79° F. The dormant insects were brought out from their hiding places by the heat of the room.

The sensitiveness of mosquitoes to meteorological changes varies, some being hardy, others delicate; thus *C. fatigans*, Wied, and *C. impellens*, Walk., are fairly active in Northern India throughout the year (GILES). Extra heat operates on mosquitoes similarly, hence we find that in the Punjab and the United Provinces after a brief reappearance of anophelines in spring they once more disappear and remain hidden during the severe heat of May and June. Most of the *Stegomyia*, *Panopletes*, and other species associated with the rainy season, occur for several months only, and remain hidden during extremes of weather.*

SPECIFIC CAUSE OF MALARIA.

THE MALARIAL PARASITES OF MAN IN INDIA.

A.—EXAMINATION OF NORMAL BLOOD.

Before commencing the study of malarial parasites it is well to make oneself thoroughly familiar with the microscopical characters and appearances of normal blood in both fresh and stained specimens—the different varieties of leucocytes, and the size, colour, shape and appearances of red cells, etc. This should be made the basis of hæmatological knowledge. We should be at once able to recognise artefacts as such, vacuoles, fissures, variations in crenation and buckling in red cells, ordinary dirt, and hæmaconiæ or blood dust; we should be able to diagnose the various forms assumed by the squashed nuclei of leucocytes, and the different forms and appearances of hæmatoblasts in stained films and to diagnose these latter whether in clumps or singly, and be able,

* GILES, *Gnats or Mosquitoes*, 2nd Ed.

without any hesitation or doubt, to tell whether a stained blood platelet on or under a red cell is a malarial parasite or not.

After acquiring a familiarity with the microscopical characters of normal blood, it is well to begin the study of malarial plasmodia on typical cases that have not yet had quinine. The blood of cases of malaria should be examined as soon as they come to hospital and before they have had quinine. Such cases will, of course, be seldom met with in the in-patients of ordinary hospitals. They are best found in the children of bazars, villages and native quarters generally. If there is likely to be more than an hour before examining the fresh films, they should be ringed with vaseline and put into a little slide-holding box, one into which the slides slip edgewise and are kept separate. In films for staining, several slides may also be carried in a sheet of note paper, the slides being rolled one after another so as to have a layer of paper between each of them.

Necessity of cleanliness in blood examinations.—*Cleanliness is of great importance*; it gives more reliable results and considerably lessens the chances of erroneous conclusions being drawn in doubtful cases.

To clean dirty slides.—Rub with turpentine, benzin or xylol to remove any adherent oil or grease. Wash with soap and water, rinse in clean water, dry and rub thoroughly with a clean cloth. For ordinary work it is usually sufficient to dip the slide in water and *wipe dry* with a clean soft cloth

Clean slides are essential.—Dirty slides and defective staining are responsible for much confusion in malaria blood work, and for many of the mistakes that are made. For the coarse work of diagnosis only, in the hands of an expert, these defects are perhaps less material, but he is the person who would be least likely to work with dirty slides or to imperfectly stain his films.

To clean patient's finger.—Under ordinary circumstances all that is necessary in malaria blood work is to wipe the tip of the finger with a clean dry cloth. If the finger appears dirty it should be washed with soap and water, followed by methylated spirit. It is impossible to get blood films from a moist, sweaty or dirty finger.

To make blood films.—In adults and children the palmer aspect of the pulp or tip of a finger is to be used. Some prefer the back of the finger just above the root of the nail. In young infants the lobule of the ear is more convenient. The prick with the needle should be made pretty firmly and sharply, but not deeply. One of the operator's fingers may, if necessary, be kept against the needle about $\frac{1}{10}$ inch from the point; this safeguards from too deep penetration.

After the finger is pricked the first droplet in wiped off. The next and succeeding droplets, which should not be larger than the head of a pin, are received on the slides about half an inch or so from one end. The middle of the shaft of the needle is now laid on the droplet and allowed to remain for a second until it has spread along the shaft between it and the slide. The needle is now carried smoothly along the slide to the other end. To make films with even, straight edges, it is a good plan to keep the end of the thumb in contact with the edge of the slide as the needle glides along the latter. The slide is then moved through the air rapidly until the film is dry. The more rapidly the blood dries the better the red cells remain for staining. The film should be thin and uniformly spread—a single layer of red cells just barely or not quite touching each other is the object aimed at. As far as possible the upper and lower edges of the film should have a straight line parallel with the edges of the slide; this helps one to make a differential count of the leucocytes should they be necessary. The right hand end of the smear should be forked or pointed.

Fixing films.—No fixative is required with Leishman, Giemsa, and Ziemann stains. When ordinary Romanowsky solution is used, the best fixative is *absolute alcohol*. In this country *methylated spirit* may be used, but it does not give such clear well-defined pictures of the cell-elements and parasites as when absolute alcohol is used. The alcohol may be kept in a wide mouthed glass-stoppered bottle, and the films placed in it for about 5 minutes. *Heat should not be used for fixing blood films* except under some special methods of staining such as Ehrlich's tri-acid stain, in which heating is an essential part of the process.

It is necessary to remember that before the film is fixed the hæmoglobin of the red cells is dissolved by water if it comes into contact with them. The smallest amount of moisture is detrimental to staining. So much so is this the case that the moisture of the air during the monsoons, the mere breathing on the slide, or atmospheric moisture absorbed by the alcohol used for fixing, are all sufficient to give defective results.

In a good fresh film when the preparation is held up to the light, there is a clear area in the middle having no signs of a granular appearance, and looking as if there were no blood in it; this area has the red cells in a single layer and barely touching each other. When this middle portion of the film is granular or reddish there are several layers of red cells heaped up, and young forms of plasmodia are quite indistinguishable in it. The red cells should be seen as a single layer of clear circular regular discs just touching and not overlapping.

In making a diagnosis one slide at least should be stained by Romanowsky as parasites are often missed in fresh films.

Fresh preparations.—For fresh preparations the droplet of blood is received on the centre of the slide and the cover-glass gently lowered on to it. A good preparation shows the blood in the central part as almost transparent, around this an opaque yellowish red ring, and outside a decided red part. If the blood is not to be examined at once it should be ringed with vaseline.

For microscopical observation a good immersion lens and an Abbé condenser are necessary, although it is possible with a good dry system of lenses reaching 500 diameters to recognise the different forms. LAVERAN made all his important original discoveries with dry lenses of comparatively low powers, and described even the smallest malarial parasites with them.

In fresh films the light must be shut off to such an extent that the field is just clearly seen; too little is better than too much light, as the early stage of the parasites of malaria is difficult to see with a bright light The beginner should first look for red cells containing pigment granules. These will probably be found in the intermediate or older forms. Later he should look for the smaller opaque unpigmented or slightly pigmented young forms.

With stained preparations, after preparing and drying the film, a drop of cedar oil is dropped on to the stained blood and the oil immersion brought down to it. It is unnecessary to use Canada balsam and a cover-slip. If the slide is required for further examination at a later date, allow a few drops of xylol to fall on the cedar oil, drain it off and dry; the xylol removes the cedar oil; then put the labelled slide away in the cabinet.

When a preparation is ready for examination the condenser is racked up, the immersion lens lowered with the coarse adjustment and finally focussed with the fine adjustment.

When working without a mechanical stage, fix the right end of the slide to the stage with the corresponding clip, with the fine adjustment focus upwards first, then, if necessary, downwards. If this is done there is no risk of jamming the objective lens through the slide. Begin examining at the upper edge of the film and then go towards the forked or tongued part; it is along this line and the forked part that parasites are usually more numerous when present.

Ross' thick film.—Take a fairly large drop of blood on a slide, spread it out with the needle to form a circle half an inch in diameter, and allow it to dry. One should be careful if using a spirit lamp or Bunsen burner for this purpose not to dry the blood too rapidly. Pour No. 1 Romanowsky solution (Eosin 1—20000 water) on the film several times during 15 or 20 minutes, then wash off with distilled or tap water. Pour No. 2 Romanowsky solution (Methylene blue 1—1000 water in pure carbonate of soda) on the slide for half a minute, wash off with distilled or tap water, dry and examine in the usual way. By this method we may often detect plasmodia which are not discoverable in the ordinary thin smears.

The best time for finding parasites in the blood in malarial fevers is from several hours before the beginning of the paroxysm to the time it reaches its height, and again when the temperature has become normal. In India we occasionally meet with negative findings in malarial fevers, especially at the beginning of an infection, even when quinine has not been given. One has every now and then found parasites absent at the first outburst of fresh infections when succeeding paroxysms revealed them. It would be a useful preliminary to the study of human malarial blood to examine the bloods of birds known to carry avian malarial parasites. These can always be obtained—for Hæmoproteus, the sparrow, and for Halteridium the ordinary pigeon. They have this advantage also that they occur in the blood of these birds throughout the year.

The malarial parasite in its normal state is endoglobular (intra-corpuscular). Hence it is well to be on one's guard in diagnosing *free parasites*. They, of course, do occur in the form of spores on the slide (they have been described by different writers in both fresh and stained films), and in the form of free crescents and spherical gametes, but their normal habitat in the blood is within red cells.

As the parasites are endoglobular it is necessary that the red cells be spread out in a single layer lying flat, and not edgewise or in rouleaux. We should also remember that red blood cells are delicate structures and require delicate handling.

In using different stains, the method described by the inventors of the stains should be strictly followed until sufficiently experienced to embark on personal modifications or new methods.

In cases of malarial infection a single five grain dose of quinine will sometimes cause all parasites to disappear from the peripheral circulation, a 15 grain dose will very frequently do so. Hence we always inquire whether the patient has taken quinine curatively or prophylactically before examining the blood.

When quinine prophylaxis is practised the finding of malarial plasmodia in the blood in cases of malarial fever is rendered more difficult—in such cases the relative increase of large mononuclear leucocytes (which seems to be characteristic of protozoal blood infections) may be of assistance in making a diagnosis.

A few hours' demonstration by one familiar with the appearances of malarial hæmosporidia in fresh and stained blood will save much time, and to a large extent eliminate errors in diagnosis in future cases. Both fresh and stained specimens should be examined and compared.

Accessories required for blood examination.—In ordinary blood work the only articles required besides the miscroscope and lenses are glass slides, thin cover glasses (circles $\frac{5}{8}$ inch diameter), pair of cover glass forceps, alcohol, straight surgical needle, and one of the Romanowsky staining fluids.

Those who are engaged in hæmatological work usually carry with them a small case containing straight surgical needles, slides, and a few glass curved tubes or capsules for blood for making sera diagnoses. Such a case can be made out of a piece of ordinary chamois leather, made to fold like an ordinary pocket letter case, and containing a few pockets for the slides, etc.

Romanowsky stain.—In studying malarial plasmodia, the original Romanowsky stain, or one of its modifications (Leishman, Giemsa, Jenner, Wright, Ziemann) is essential; any one of these stains the chromatin of the nuclei of parasites red, and the protoplasm blue.

The basis of all Romanowsky stains is as follows :—" A solution of methylene blue that has been acted upon by carbonate of soda or other alkaline reagent, becomes partly converted into various polychrome derivatives, *e. g.*, methylene azure and methylene violet. These bodies are in solution. When they are acted upon by a solution of eosin there results a precipitate, and this precipitated body (or bodies) possesses the property of staining the nucleus an intense heliotrope red colour (chromatin stain)."* The staining may be done at the moment of mixing the methylene blue and eosin solutions, when it occurs in the nascent state; or the precipitate may be allowed to form, and subsequently be dissolved in a solvent such as methyl alcohol (as occurs in Leishman and Giemsa stains), and finally be precipitated out of solution by the addition of water at the time of staining.

The Romanowsky stain, which one prefers, is that recommended by STEPHENS AND CHRISTOPHERS,† and can now, with the supply of staining materials kept by chemists in this country, be prepared and always obtained. This gives such ready, reliable and accurate results, whether dealing with fresh specimens or with slides that must be kept for some days before staining, that one quotes the formulæ for it here.

The following materials are necessary for the making of the stain, *viz.* :—

Medicinal methylene blue, eosin extra (B.A. or A.G.), or simply pure eosin for blood staining, and sodium *carbonate* (pure).

Two stock solutions are made :—

Solution A.—Methylene blue	... ...	1·0 part.
Sodium carbonate	... ...	0·5 part.
Water ...	... ...	100 parts.

This solution is placed in a hot incubator or by the kitchen fire, or in the sun, for two or three days. By this time a deep purple

* STEPHENS and CHRISTOPHERS, *Practical Study of Malaria*, 3rd Ed., p. 21.
†*Ib.*, p. 22.

colour will be noticed at the edges of the liquid. The colour depends upon the formation of a new red body, which, combined with eosin, forms the active staining principle of Romanowsky. Until the purple colour is developed the solution is quite useless.

Solution B.—Eosin	...	...	1 part.
Water	...	...	1,000 parts.

For staining, these stock solutions are diluted one in twenty respectively with water, *i.e.*, five parts of the stock are made up to one hundred parts with water.

To Stain.—Equal portions (about four c. c.) of each solution are poured into a porcelain or any other convenient dish. Mix by shaking and after fixing them in absolute alcohol for from 5 to 15 minutes, put the slides in immediately. The amount of stain required, once measured, may be marked on a glass tube with a piece of gummed paper, and is thus always ready. On rocking the solution in the dish a red stain will be seen at the sides; this indicates that the staining is proceeding well. Leave the slides in the stain any time from ten minutes to half-an-hour or longer. Wash off the excess of stain with water, and allow them to drain or dry them with blotting paper, but do not dry them by heating over a flame. The red corpuscles may have a bluish tinge. This can be got rid of if desired by washing in water, or very rapidly, in equal quantities of spirit and water.

Placed under the microscope, while still wet, the blood platelets should appear as ruby red granular masses; if they are bluish the film should be replaced in the staining solution. Slides may be decolourised to any required extent by soaking in water, in fact, if left long enough the stain is entirely washed out. Such a specimen can, however, be easily stained a second time. The exact position and relations of pigment are best seen in specimens lightly stained, as deep Romanowsky staining may completely obscure pigment.

One knows of no better method, except unstained specimens of fresh blood examined at once, of differentiating between male and female gametes of any form of malarial fever, than that of the use of the Romanowsky stain made after the above formulæ. The female crescent takes this stain well, and it at once demonstrates the close grouping of the pigment in ring form, with one or two large masses of chromatin in the centre; whilst in the male crescent the stain of the cytoplasm is fainter, the pigment is seen to be scattered, and the chromatin grouped in four or five or more masses irregularly.

The various modifications of Romanowksy-Leishman's stain gives very satisfactory results for quick work, whether in tabloids or crystals, but personally one has had less variable results from the use of the solutions named above, probably because of greater acquaintance with their peculiarities under varying conditions. Leishman's stain is convenient to carry about and both it and pure methyl alcohol are now procurable at all large chemists in this country.

Leishman's stain.—This is the precipitate got from the action of a watery solution of eosin on a watery solution of methylene blue *previously treated* with an alkaline such as carbonate of soda. The formation of azure bodies is much more rapid in alkaline methylene blue than in the ordinary Jenner stain. The precipitate is washed and dissolved in methyl alcohol. In making the stain we employ methyl alcohol 10, Leishman's stain in 'soloids' 0·015 gramme.

Staining is effected by throwing the neutral body out of solution by distilled water. The stock solution of this does not keep well in India.

B.—Malarial Parasites.

Malarial fevers are caused by forms of protozoal organisms which invade the red cells, and gain access to these cells through certain species of anophelines who have bitten persons already infected by those organisms. In ordinary circumstances these parasites are unable to leave the blood of man.

Evidence regarding the specific nature of malarial parasites.—The main reasons for the belief that these parasites are the cause of malarial fevers are summarised by Sir Patrick Manson as follows :—

1. The occurrence of the parasites in the blood is practically always, sooner or later, associated with the clinical phenomena of malarial infection.

2. Malarial fever throughout, or at one time or another during its course, is invariably associated with the presence of one or other of these parasites in the blood.

3. The phases of a malarial fever bear a definite relation to the phases of the life-cycle of the particular parasites present in the blood.

4. That absolutely characteristic feature of malarial disease—malarial pigmentation of viscera—is fully accounted for by the pigment-forming property of the parasites.

5. Intravenous or sub-cutaneous injection of blood from a case of malarial infection—that is, of blood containing the parasites—is generally, after an incubation period of eight to twelve days, followed by an attack of malarial fever, and by the appearance in the blood of the persons injected of the same species of malaria parasite.

6. The administration of quinine, which brings about the cessation of the clinical symptoms of acute malarial infection, rapidly causes most phases of the parasite to disappear from the blood.

7. If, after they have imbibed malarial blood, certain species of mosquitoes be dissected at serial intervals, the evolution of the malaria parasite can be followed in their tissues until, finally, the germs of the parasite can be tracked into the cells and secretion of salivary glands of the insect.

8. If after a week, or thereabouts, a similarly-fed mosquito bite a hitherto uninfected man, in many instances, after a few days, that man will exhibit the clinical phenomena of malarial infection and the characteristic parasite in his blood.

9. A non-immune, if effectually protected against mosquito bite, will not contract malarial disease however long he may live in highly malarious localities.*

Classification of malaria parasites.—Malarial parasites belong to the SUB-KINGDOM *Protozoa*, the Phylum Sporozoa, class Telosporidia, order Hæmosporidia, and sub-family Hæmamœbida, genera *Plasmodium* and *Laverania*.

The Sporozoa are protozoa without mobile organs; reproduction is by sporulation; they are always parasitic.

Sporozoa are true unicellular elements consisting of protoplasm, a nucleus and nucleolus (or karyosome). They are all characterised by being endocellular parasites (cytophages). They have also an amœboid phase of life, during which, in the absence of a cell wall, they are animated by characteristic protoplasmic movement. They multiply by forming spores, hence the name.

The Phylum *Sporozoa* is divided into two sub-classes—*Telosporidia* in which reproduction (sporulation) follows when growth is complete, and *Neosporidia* in which sporulation proceeds during the process of growth. In connection with malaria the *Neosporidia* do not concern us.

The *Telosporidia* are sporozoa in which the act of reproduction ends the individual's life, the entire protoplasm being used in forming spores

The *Telosporidia* are divided with three orders:—

ORDER 1. *Gregarinida.*—The young stages only are cell parasites, the adult organism living in fluids within the cavities of animal hosts. There are no human *Gregarinida*.

ORDER 2. *Coccidia* (Coccidiomorpha).—Intra-cellular parasites mainly in the epithelial cells of vertebrate and invertebrate hosts; reproduction is anisogamous, male and female cells concerned in the process

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* *Tropical Diseases*, 3rd Ed., p. 3.

are microscopically distinguishable. Spores have shells without polar bodies, mostly with several sporozoites. Human parasites have been traced mainly to the genus Coccidium.

ORDER 3. *Hœmosporidia.*—These are sporozoa of small size living in the blood corpuscles of vertebrates; they exhibit amœboid movements, present alternation of generations; the spores are naked. The human parasites belong to the genera Laverania, Plasmodium, and Piroplasma, the first of which includes the malignant tertian parasite (*Lavarania malariœ*, Gr. and Fel.), the second *Plasmodium malariœ*, Laveran, the parasite of quartan fever, and *Plasmodium vivax*, Gr. and Fel., the parasite of benign tertian fever.*

Malarial parasites, like all protozoa, are unicellular animal organisms; like all sporozoa they are without organs of locomotion, they reproduce by sporulation, and are parasitic.

Amongst the sporozoa simple non-sexual division cannot be carried on indefinitely; to effect this a sexual cycle must be introduced, and in the case of malarial parasites this cannot be effected whilst the parasite is still in the human body. So far as we know at present this can only be brought about through the medium of certain species of anophelines.

In the human body the malarial parasite tends to exhaust its powers of multiplication, and if the patient has been able to battle against its ravages, he recovers. The parasite cannot gain access from one man's blood to that of another except through anophelines.

Comparison of developmental processes in malarial parasites with Coccidia and Protozoa generally.—The processes in the development of malarial parasites are the same as those which occur in coccidia, and the biological terms employed in describing these processes are identically the same in each case. The one great difference is that in malaria an intermediate host, some species of anopheline, is required to carry the disease from man to man, whereas in coccidia no such host is necessary, as the encapsuled sporozoites, discharged with the fæces are ingested, and on being set free by the digestion of the capsule, the sporozoites find their way to the epithelial cells of the intestinal mucous membrane or to the bile capillaries. The term used in connection with the various stages of the development of malarial parasites and protozoa are given in the following useful table† :—

* The terms *hæmosporidia*, *plasmodia* and *malarial parasites*, frequently used in this book are employed generically and not to any particular species of malarial parasite.

† DANIELS and WILKINSON, *Tropical Medicine and Hygiene*, Part I, p. 9

Scientific terms.	Description.	Terms commonly used in describing the development of malarial parasites.
Schizogony ...	The asexual or endogamous cycle...	Cycle in man.
Schizont ...	The parasite of the asexual cycle...	Sporocytes.
Merozoite (spore) ...	The young parasites resulting from asexual division.	Spores.
Gametocyte ...	The potentially sexual forms, male and female.	Gametocyte—crescents and spherical gametes.
Microgamete ...	The fertilising element or elements, "spermatozoa" discharged from the male gametocyte	Flagellum or microgamete.
Macrogamete ...	The female sexual form ...	Macrogamete.
Sporogony ...	The sexual or exogenous cycle ...	Cycle in mosquito.
Ookinet ...	The motile fertilised macrogamete	Travelling vermicule.
Oocyst	The non-motile fertilised macrogamete, applied whether originally motile or not.	Zygote.
Sporoblast ...	The primary division of the protoplasm of the oocyst (zygote).	Blastophore.
Sporozoite ...	The final product of the sexual development formed from the sporoblasts or blastophores.	Zygotoblasts, blasts, or sporozoites.

Asexual cycle in man.—It begins as a sporozoite or an amœbula which enters a red cell, grows in it and produces other spores asexually. This goes on indefinitely in the host and represents the *asexual* or *endogenous cycle* of its life-history.

Sexual cycle in the mosquito.—In the *sexual* or *exogenous cycle* some of the spores in red cells do not sporulate but develop into male and female gametes in the red cells. Now a second host is needed, in this case some species of anopheline, which feeds on the infected person. The mosquito abstracts male and female gametes from the blood and lodges them in the stomach. The *zygote* is produced by union of male and female. This zygote burrows into the stomach wall of the mosquito and grows in its body cavity, attaining to ten times its previous diameter, and 1,000 times its bulk, producing spores. It is now almost visible to the naked eye and packed with *sporozoites*. These sporozoites escape and find their way into the salivary glands whence they reach the human being; on entering the blood they penetrate the red cells and begin the process of sporulation. This great increase of reproductive power in the sporoblasts in the mosquito must be considered as a secondary adaptation of a kind common in all forms of parasitical organisms, whereby the chances of disseminating the parasite amongst fresh hosts is greatly increased by the vast number of sporozoites or germs produced from each individual.

The zygote resulting from fertilisation is at first a freely moving gregarine like body, the *vermicule* or *ookinet*, which seeks out actively and penetrates the epithelial cells of the stomach wall.

The period for complete sexual development and reproduction of sporozoites in the anopheline is six to ten days.

Without sexual reproduction, the malarial organism would, after asexual multiplication for a number of generations, become exhausted and die out (see, however, remarks on *Relapses*, p 118, *et seq.*). As far as the individual person is concerned this is what actually takes place, when properly treated by quinine; for then the young forms, which would eventually have given rise to sexual forms, are destroyed. Hence quinine properly given is a definite disinfectant of the blood in the bacteriological sense. There is experimental evidence to support the hypothesis that conjugation of male and female gametes involves a process of rejuvenescence whereby the cell is stimulated to renewed activity.

When the female anopheline sucks the blood of a malarial patient into her stomach, she takes in the parasites with the blood in all its stages of development—young amœbulæ, fully developed schizonts, rosettes, and it may be gametes. All stages of the schizogonous cycle are digested in the stomach along with the blood corpuscles. Gametocytes when sufficiently mature are, however, able to resist the action of the digestive juices and continue their development, for as soon as they are liberated from the remains of the red cell (which are digested) in which they grew, they assume a spherical form (if they have not already reached this stage) and give rise to gametes. The maturation, full development and conjugation of gametes occurs in the stomach cavity of the mosquito.

Malarial hæmosporidia in the mosquito.—The *macrogamete* in simple tertian and quartan infection is spherical, in malignant tertian the female is crescentic; the *microgametocyte* in simple tertian and quartan is spherical, and in malignant tertian crescentic; the *microgamete* is the liberated flagellum of the microgametocyte; the *sporont* is the result of the fertilisation of the macrogamete by the microgamete; the *ookinet* (vermicule) is the mobile stage of the sporont; the *oocyst* is the cystic stage of the sporont; the *sporoblasts* are developed within the oocyst; *sporozoites* are developed within sporoblasts and liberated by rupture of the oocyst, are introduced into man by anophelines, and are capable of beginning the human life-cycle by infecting the red blood cells.

C.—Description of Malarial Parasites.

Microscopically, the malarial parasites, even the smallest rings, are comparatively gross bodies, and in properly stained preparations with an immersion lens of $\frac{1}{12}$ inch are always readily seen. In very meagre infections, with only a few on a whole slide, they may require a good deal of looking for, but with a mechanical stage and the aid of a finder. if the film is looked through systematically, beginning at the left hand top corner of the film, and working up and down while the stage is moved to the left throughout the smear, even a very slight infection with parasites in the peripheral blood will seldom be missed.

Fresh preparations.—With *fresh* coverslip *preparations*, when the parasites are in the form of unpigmented amœbulæ, there may be some difficulty in finding them, but in simple tertian and quartan, when granules of pigment begin to form early, these are readily recognised, whilst gametes are more readily seen in fresh than in stained films, as the pigment in them is very conspicuous, is often found in a "boiling" state, and the sexes are easily distinguished from the arrangement of the pigment which contrasts with the colourless protoplasm of the parasite.

Stained preparations.—The *staining reactions* as regards the nucleus and protoplasm are the same in all varieties of malarial parasites. In the Romanowsky stain the chromatin is the only portion of the nucleus which takes the stain and it stains a bright red, lying in the unstained vesicular nucleus. Around the nucleus in young forms is always a small amount of protoplasm which stains a delicate blue, and incorporated in the protoplasm is the scanty pigment.

In all varieties of the parasite, as growth proceeds, the chromatin scatters through the cytoplasm; when full grown, a distinct nucleus is not visible, and the protoplasm is now uniformly distributed. When segmentation is about to occur the pigment is gathered towards the centre of the parasite and the chromatin is found in small clumps, forming a definite part of the newly formed segments. At the time of segmentation the chromatin is collected into small masses lying in unstained areas which are the vesicular parts of the nuclei, and these latter are surrounded by thin rings of protoplasm which stain deep blue.

In the *crescents of sub-tertian* the parasite consists of a large amount of protoplasm and a packed mass of chromatin at the centre or one of the poles. The *flagellated parasite* stains the same as the parasite except that a narrow line of chromatin can be detected in each flagellum. The chromatin is gathered towards the centre of the flagellum before it is set free from the microgametocyte, the rest of the flagellum staining uniformally light blue, the chromatin being a bright red.

All varieties of the parasite in the first stage of invasion of the corpuscle are ring-shaped, with a small dot of chromatin surrounded by an unstained area, the nucleus, and this again surrounded by a small amount of blue protoplasm.

Fresh preparations are very useful in studying the life-cycle of malarial hæmosporidia, but the exact morphological relations can only be demonstrated by staining reactions.

Stained preparations are most convenient, especially when films cannot be examined at once. On the dried film the name of the person and date is written with the needle or grease pencil. They may then be stained and examined at once, or kept for months and then stained.

Flagellation.—When flagellation is about to take place the whole microgametocyte vibrates and oscillates. The vigour with which the flagella move is often seen to be sufficient to cause deep indentations in the red cells which, however, are only momentary, as the elasticity of the red cells enables them to recover their normal shape at once. The movements of the flagella continues as a rule for from 20 to 30 minutes; but may occasionally be seen after even two hours. In their most active condition the individual flagella cannot be recognised, as their movements are quicker than the eye can follow ; as the movements become weaker they are seen distinctly ; they then become more intermittent and eventually cease. At this stage the flagella that have not broken away are seen to be attached to the body-protoplasm of the microgametocyte. The flagella are from two to four times the diameter of a red cell in length. The movements of detached flagella are very similar to those of an eel in water or a snake along the ground ; they are usually of a lashing character, and in fresh films are seen to agitate the red cells violently. They are difficult to follow in their wanderings amongst the red cells.

Points to observe in malarial blood films.—The different points to inquire into in a blood examination of the plasmodia of malaria are:—The stages of the parasite met with in the peripheral blood ; character of amœboid movement in the plasmodia ; effects of the parasite on the erythrocytes ; dimensions of the parasites, number of merozoites, character of the sexual forms, and character of the pigment.

Endoglobular cycle.—This is similar in all essentials in the three species of malarial parasites, each, however, having its own characteristics.

Schizogony is easily studied in the benign tertian forms of malarial infection as the plasmodia are in the peripheral circulation ; the same holds good with quartan, but the cycle is spread over a longer period. In the unstained specimen of the quartan parasite there is a small dot in the centre which is the nucleus and is often visible. In malignant tertian schizogony cannot be studied as it goes on in the internal organs. In it multiplication of the nucleus of the schizont commences by a primitive form of mictosis, but as nuclei increase in number, the method of development is that of a type of multiple nuclear fission (SCHAUDINN). Very occasionally a fully developed schizont is seen in peripheral blood.

Amœboid movement of parasites.—In simple tertian the *amœboid movement* is most active and continues longest; the amœbulæ are very active and vigorous (hence the name, *vivax*, lively); they spread out pseudopodia in all directions continuously. In quartan parasite the amœboid movement is sluggish but quite visible. In *sub-tertian* the movements are very lively in the youngest unpigmented stage. In all forms the movement slows down as the intracorpuscular parasite is acquiring its full size.

In all varieties of parasites the young forms (*amœbulæ*) are so perpetually changing their shape that it is difficult to give any description of them; they are seen to alter their form constantly under the eye. It is only after they have been acted on by exposure to external influences, which bring about their death, that they have a constant shape, and this is usually a ring form, or occasionally, a disc shape.

"Crescents possess no amœboid motion, yet show the power of gradually changing their shape."—(MANNABERG).

Multiple infection of red cells.—It frequently happens in severe infections, especially of malignant tertians, that two or even three or more parasites occupy a single red cell. MANNABERG has found as many as six rings in one red cell. In a severe simple tertian infection in a rifleman of the 2-39th Garhwal Rifles one recently saw five "rings" in one red cell. The preparation was sent me by Captain B. E. M. NEWLAND, I.M.S. In a case seen a few weeks ago, that of a personal servant, five malignant tertian rings were counted in one cell. We constantly see double infection of a single cell in cases of simple and malignant tertian fever.

Effect on red cells.—In *quartan* the red cell retains its normal size, some being smaller; its colour also remains normal. In *simple tertian* the infected red cells increase considerably in size; they also become paler. The effect of *sub-tertian* parasites on the size of red cells may vary; at times they are diminished, and mostly they are unaffected or slightly increased; sometimes they are irregular or crenated, and the colour may be heightened or lessened.

Size of the parasites.—In the different phases of their development the malarial parasites vary from 1 to 10 microns in diameter, the first representing the smallest rings of malignant tertian, the latter the full-grown parasites of quartan and the different forms of gametes; the fully grown benign tertian however frequently has a diameter of 16 microns.

The ordinary dimensions of a full-grown crescent is 8 to 10 microns (sometimes however reaching 15 microns) and 2 to 3 microns broad about the middle.

Characters of the pigment.—The pigment of malarial parasites may occur in very fine dust-like particles, or as large granules, thin lines, fine needles, grains or in clumps. The largest needles or lines of pigment are not more than 1 micron in length. When they run together the pigment granules and lines form clumps. When in larger masses the pigment is brownish black; when in fine lines, needles or granules, it is reddish brown. The parasite lives in and devours the red cell. It metabolises pigment from it. The excreta of the parasite remain in the cell until the cell bursts, when hæmozoin* is discharged into the blood. The pigment appears early in intra-cellular life, and when present, renders it easy to see the parasite in fresh blood. The size of the granules of pigment vary in the different species of parasite. As the pigment is disposed in the protoplasm of the parasites, it shares with them the amœboid movement when the parasites are still living. "In addition the pigment shows a second communicated movement which is most marked in the adult sexual forms of the parasites. This consists in a more or less to and fro wavering of the pigment elements. When slight the pigment granules move sluggishly, scarcely changing their place, but when marked they whirl back and forth like a swarm of gnats." (MANNABERG). This last is the so-called "boiling" or *bubbling movement* of the pigment.

Malarial pigment is unaffected by strong mineral acids, but it is cleared by weak alkalis, and then acquires a yellowish or reddish brown colour. Malarial pigment is dissolved by ammonium sulphide. It does not give the blue reaction of iron with ferrocyanide of iron. It gives the same micro-chemical reactions as the pigment of melanotic sarcomas. It does not give the reactions of hæmoglobin in clots of the brain or elsewhere.

The pigment in quartan is chocolate coloured, seen as comparatively large brown granules mixed with small reddish ones. In simple tertian the pigment is more straw-coloured faint pale ochre colour or greenish, and the granules very small.

In the unstained specimen of the quartan parasite there is a small dot in centre which is the nucleus and is often visible; it is not pigment.

Sporozoites.—*Sporozoites* are thin, somewhat filamentous in form, sharply pointed at both ends, with a thicker central portion, in which the nucleus is lodged. The sporozoites are naked gymnospores, similar to the *eimeria* in Coccidia. In the red cells the sporozoite rounds itself off and develops into an amœboid trophozoite, and then grows at the expense of the hæmoglobin. The sporozoites of the different species of parasites are not distinguishable from one another.

* *Hæmozoin* is the term given by SAMBON to malarial melanin. The term *black pigment* is inappropriate, indefinite and inaccurate as the colouring matter is never actually black in human malaria; it varies from yellow to brownish black.

General characters of malarial fevers.—All forms of malarial fever arise from the presence in the blood of one or other form of the parasites of malaria. Two or even three (which is rare) forms may invade the blood at the same time. These fevers are characterised by—(1), periodically recurring paroxysms of intermittent fever; or (2), continued fever with marked remissions; or (3), a pernicious and often fatal form of fever; or (4), a chronic cachexia associated with irregular fever, anæmia, and enlargement of the spleen.

In India there are, as far as we at present know, only three forms of the malarial parasites, giving rise to three forms of malarial fever met with:—

1. **Quartan parasite.**—*Quartan ague,* due to the *Plasmodium malariæ,* in which the attack comes on every 72 hours. In this form the parasite invades the red blood corpuscles, sporulates, and in doing so forms from 6 to 12 merozoites, which give the invaded red cell a daisylike appearance before it ruptures to set the merozoites free in the blood. In the human blood the life-cycle of this parasite is asexual and lasts 72 hours. Two or more generations of the parasites may carry on their life-cycle in the blood simultaneously, giving rise to double or triple quartan ague.

2. **Simple tertian parasite.**—*Simple tertian or benign ague,* due to the *Plasmodium vivax,* in which the attack comes on every 48 hours. In this the parasite invading the red blood cells also forms spores, which, when full developed, are from 12 to 24 in number, and, before the rupture of the cell, look like the petals of a rose inside the red cell. The life-cycle of the parasite is 48 hours. Two or more generations of the parasite may in simple tertian also carry on their life-cycles simultaneously, giving rise to double or triple (rare) tertian ague. Stained by ROMANOWSKY in many cases the decolorised infected red corpuscles display a number of deep red granules—Shüffner's dots.

The vast majority of the cases of malaria in India consists of simple tertian, which is considered by most authorities to be the easiest form of malarial infection to eradicate from a locality and from infected persons. This does not correspond altogether with the experience of many experts in India. Notwithstanding statements to the contrary, the largest number of relapses occur in cases of simple tertian fever—this is accounted for by the fact that this is the predominating form of malarial fever of India. During the last ten years one has had opportunities of watching and following relapses in localities where there is no initial malaria, and 79 per cent. of these were simple tertians, over 20 per cent. malignant tertians, and only a small fraction quartans. The generally accepted statement also that perniciousness is confined to malignant tertian is opposed to one's personal experience, as we have seen such conditions as algid paroxysms, choleraic attacks, secondary pernicious anæmia, cerebral attacks, and even hyperpyrexial phenomena, associated with simple tertian infection, whilst a fair proportion of cases of repeated simple tertian relapses or re-infections end in malarial cachexia. In discussing the subject with men of wide knowledge of Indian malaria, it has been ascertained that one's experience in this respect is not exceptional.

In both quartan and simple tertian ague, the gametes (sexual forms of the parasite) are spherical in the human blood.

Malignant tertian parasite.—*Malignant tertian fever* due to *Laverania malariæ*, Grassi and Felleti, in which the typical attack comes on every 48 hours; but, as frequently there are two (or more) generations of the special parasite undergoing development simultaneously in the blood, the attacks often occur daily, or irregularly. In this fever the parasite invading the red blood cells forms multiple small spores in the red cells of internal organs (spleen, brain, red marrow of bones, etc.). The spores vary from 10 to 20 or more. The fully developed intracorpuscular form is not seen in the blood removed from the finger for examination. Peripheral red cells contain small ring forms and small amœboid bodies, sometimes in large numbers. The gametes or sexual form of this parasite are peculiar in having a crescentic shape, and hence called "crescents." After the paroxysms have continued from five days to a fortnight, these large oval and crescentic bodies (malignant tertian gametes) are met with in the peripheral blood; they contain collections of coarse pigment granules, which make it easy to see them in fresh preparations.

Special characters of malignant tertian fever.—Malignant tertian fever is specially characterised by its disposition to irregularity, and to the production of a remittent or sub-continuous fever, and by the frequency with which symptoms of a pernicious type develop. The remittent or continued type of the fever in all probability is due to the grouping of the parasite in the blood, the intracorpuscular segmentation of which extends over comparatively long periods of time, creating paroxysms of long duration, which, from their peculiar tendency to anticipation and retardation, become subinterant. As the normal cycle of development of the malignant tertian parasite lasts 48 hours in typical cases, the intermittent fever to which it gives rise has well marked characteristics.

The greater part of the life-cycle of the malignant tertian parasite is passed in the internal organs and larger blood vessels, the younger ring forms and amœboid bodies only being met with in the surface blood. Proliferating parasites are, however, sometimes though rarely met in the peripheral blood in malignant tertian fever. Aspiration of blood from the spleen would usually show an abundance of mature forms with clumps of pigment centrally arranged with the segmented parasite around, all about half the size of the red cell. Such aspiration should not, however, be practised, unless the spleen is considerably enlarged, and then only under the strictest possible antiseptic precautions. The danger is from hæmorrhage into the peritoneal cavity, which has occurred more than once after this simple operation with a hypodermic syringe.

It is curious that just before the paroxysm the number of parasites in the peripheral blood may be comparatively few, yet phagocytes containing blocks of pigment are usually fairly abundant. This is characteristic. In cases in which malignant tertian is suspected, and where parasites are absent in fresh blood, we should never omit the examination of dried specimens of the blood by the Romanowsky method, in which the blue rings, with deeply stained purple chromatin dots, are more rapidly " spotted " than the delicate hyaline bodies in fresh blood (THAYER).

The following table gives the essential differences between the three forms of malarial parasites met with in India :—

*Table of differences between the Parasites of Malaria.**

	Benign tertian.	Quartan.	Sub-tertian.
(1) Length of cycle, *i. e.,* interval between one sporulation and the next.	48 hours ...	72 hours ...	Uncertain, often about 48 hours or rather less.
(2) Size of mature parasite.	Larger than the average red corpuscle.	Slightly smaller than the average red corpuscle.	About half the diameter of an average red corpuscle.
(3) Number of "spores"	18—24 ...	6 - 10 ...	Variable 6—30.
(4) Amœboid movement	Active and extensive.	Sluggish ...	Very active, but range of movement not extensive.
(5) Gametocytes ...	Rounded bodies	Rounded bodies	Sausage-shaped bodies, " crescents."
(6) Pigment ...	Finely divided and brown.	Coarse and black	Black and at first finely divided, but soon aggregates into coarse clumps.
(7) Effects on red corpuscles serving as host.	Causes it to swell and become paler. Does not crenate so readily. In stained specimens Schüffner's dots often found.	Red corpuscle becomes slightly smaller and darker.	The young parasite causes little or no alteration but sometimes the corpuscles become yellower - " brassy bodies." The older parasites decolorise the red corpuscles irregularly.

* From DAINELS and WILKINSON, *Tropical Medicine and Hygiene,* Part 1, p. 56.

Mixed infections.—These are by no means infrequent, the commonest being that of malignant tertian and benign tertian. Of about 900 cases examined during last year this form of mixed infection was found in eight. A remarkable case of mixed infection is recorded by Major DONOVAN, I.M.S., in the *Report of the General Hospital of Madras* for 1907. The patient was a wandering mendicant from the West Coast; he was admitted for fever, and all the species of malarial parasites were present in his blood—*Plasmodium malariæ* predominated *Laverania malariæ* next, with only a few *Plasmodia vivax*. A single dose of quinine was given, the temperature became normal and remained so for 19 days, when a rise of temperature occurred, associated with crowds of schizonts of *Plasmodia vivax*, but neither of the other two species. Another dose of 30 grains of quinine was given and after 36 days of freedom from fever a second relapse occurred, and on this occasion only *Laverania malariæ* was found in the blood. At first sight this case seems to favour Laveran's view of a single species of malarial parasite with three varieties, but it may originally have been a mixed infection, or an unaccountable alternation in the recrudescence of the latest forms. In many years observation in stations without initial attacks one has not seen any cases that showed what might be considered an alternation of malarial parasites.

Simultaneous sporulation of parasites.—In all forms of malarial fever the liberation of swarms of spores coincides with the onset of the attack of fever, the fever being probably due to the setting free, at the time of the rupture of the corpuscles, of a toxin which possesses heat-producing (thermogenetic) and red corpuscle-destroying (hæmolytic) properties.

Variation in the number of leucocytes in malaria.—In malarial fever in going over the fields of a film one frequently sees that there is evidently an increase in the large mononuclears. This can be verified by a differential count of the leucocytes. This increase is specially marked during the period following the paroxysms, and is, as a rule, absent in the pyrexial stage, during which we may have a leucopœnia. "If during a period of low temperature, this change is not found, there is a strong presumption that the case is not malarial. In some cases the change can be detected even during the pyretic period, but in these it is always more marked in the apyretic."* This change gradually disappears as convalescence advances. This is a most useful test in cases that have been treated by quinine, and one that should be made use of in all doubtful cases where parasites have possibly been missed in the early stage before quinine was administered. During the last six months one has made a series of observations on the effects of quinine in varying doses on different malarial parasites, and found that even four grains a day is in some cases sufficient, to eradicate all parasites from the peripheral circulation, and that even two grains

* STEPHENS and CHRISTOPHERS, *Practical Study of Malaria*, 3rd Ed., p. 43.

may considerably reduce their number and alter their appearance, so that in the red cells the young forms look like irregular fragments of blue protoplasm with fine dots of chromatin scattered through it, instead of being limited to the nucleus.

An increase beyond 15 per cent. of large mononuclears is considered by STEPHENS and CHRISTOPHERS to be proof of an actual or recent malarial infection, "whereas with a value of 20 per cent. it is almost always possible by long search to find an occasional parasite or pigmented leucocyte. A value of over 20 per cent. probably implies actual infection at the time of observation."

Cultivation of malarial parasites.—Up to the present time malarial parasites have never been cultivated outside the human body and the body cavity of certain species of anophelines. All efforts at cultivating them *in vitro* have failed. The malignant tertian parasite has, however, been kept alive outside the body for some days This has been done by abstraction of malarial blood by leeches, and the parasites have been kept going for a period of eight days. It is worth mentioning that no reproductive changes in the parasite were observed in this abstracted blood at any time during the eight days.

Question as to the existence of a quotidian malignant malarial parasite in India.—In the literature of malaria in India there is only one reference to a short cycle form of malignant malarial parasite and this has not been confirmed. One has written to various experts on malaria in India to ascertain their experience on the subject, and all except one state that they have not found such a parasite. From personal observations one is inclined to believe that such a short cycle parasite does exist, but the evidence one could bring forward in this connection is by no means convincing. It is necessary that we should by systematic examination of a large number of the cases now diagnosed as double malignant tertian (quotidian) put this out of doubt. This can be done by working out the cycle of the parasites found in such cases.

To follow the life cycle of malarial parasites.—In doing this we should proceed systematically. To determine the cycle of a malarial parasite it is necessary :—

"(1) To estimate the size and percentage of parasites of each size at any particular time, *e.g.*, starting with the onset of the attack.

(2) To follow each group to its period of maximum development in the circulation.

(3) To estimate the time between this period and the next appearance of young forms.

(4) To estimate the time between the appearance of an outburst of young forms and a second similar outburst.

The interval between (1) and (4) should be equal to the intervals of periods (2) and (3). It is more accurate to use a micrometer scale for measuring; but the estimation can be made with considerable accuracy without.* To establish a parasite cycle, repeated observations at definite intervals are necessary; the temperature should also be carefully recorded every two hours in working out a possible quotidian malignant, and every four hours in benign tertian, quartan and ordinary malignant tertian; if this repeated examination at short intervals is not carried out noteworthy changes may be lost sight of.

*STEPHENS and CHRISTOPHERS, *The Practical Study of Malaria*, 3rd Ed., pp. 235, 236.

PART II.- EFFECTS OF MALARIA ON MAN

A.—Pathogenesis.

At the end of the last Section one briefly considered the types of malarial fevers produced by the three different forms of malarial infection. Their legitimate place is in the present Section, but it was more convenient to deal with them in association with the description of their respective parasites.

The term *malaria* is used to include a class of diseases which occur both endemically and epidemically, and which clinically, etiologically, and therapeutically, exhibit much similarity. The main group of malarial diseases are the malarial fevers which are types of pyrexial phenomena due to invasion of the red corpuscles by different forms of *Hamœmabidœ* conveyed from man to man by certain species of *Anophelinœ*, and show a marked periodicity, and are characterised by paroxysmal intermittent fever, anæmia, enlargement of the spleen, melanæmia with deposition of pigment in internal organs, with a tendency to relapses, and finally, if the paroxysms continue, to the production of a specific cachexia.

Early effects of malarial infection.—At the moment of infection by the mosquito the proboscis is inserted into the skin and sporozoites injected, some of which find their way into the blood. It is still doubtful as to how many ordinarily get into the blood with each bite. We may reasonably assume that if the bite is very momentary only a comparatively few, if any, will reach the blood. But a mosquito inside a mosquito net will be injecting sporozoites each time it sucks up blood. The bite of a single mosquito is certainly sufficient to cause malarial infection. Judging from the thousands that are seen in the salivary glands and body cavity of infected mosquitoes on dissection, a very considerable number must be injected at each bite.

Suppose that 1,000 sporozoites find their way to the blood stream. For the moment 1,000 are of no consequence. This leads one to ask the question as to what number of injected sporozoites are required to produce malarial fever, and the percentage of infected red blood cells that produce malarial pyrexial phenomena. Ross answers these questions by stating that the red cells in man may roughly be computed as 25,000,000,000. Assuming that 1,000 sporozoites enter the circulation. Each quartan parasite segmenting at the end of 72 hours gives rise on an average to 6 to 10 spores, each benign tertian parasite 12 to 24 at the end of 48 hours, and malignant tertian about 10 to 20.

Suppose we are estimating for a double malignant tertian (quotidian) with 10 spores, the number in the blood would be—

At the end of	1st	day ...	... 1,000 × 10
„	2nd	„ ...	... 10,000 × 10
„	3rd	„ ...	... 100,000 × 10
„	4th	„ ...	... 1,000,000 × 10
„	5th	„ ...	... 10,000,000 × 10
„	6th	„ ...	...1,000,CC0,000

The weight of blood to body is about 1 to 13. One cubic millimeter of blood = 5,000,000 red cells. One parasite to 100 red cells would be a severe infection; 1 to 50 would be an extremely severe infection. Ross counted on this estimate as many as 3 billions in one case in the Mauritius. In a case of simple tertian recently seen one found 5·5 per cent. of the red cells infected. The particulars of the case are given in Part III.

An infection of 1 in 100,000 red cells is probably the lowest capable of producing pyrexial phenomena in a fresh infection; that is $\frac{25,000,000,000}{100,000} = 250,000,000$ are the least number of infected red cells required to produce fever. This is reached between the 5th and 6th day in the case assumed above. Whilst this is to a large extent theoretical, it explains, in a reasonable way, the period of incubation and the sudden accession of fever. On pp. 114, 115, one gives one's personal views as to the manner in which the number of sporozoites injected possibly influences the length of the period of incubation.

Malarial toxins.—It is assumed by most authorities as highly probable that the parasites of malaria manufacture a toxin which is responsible for the paroxysms of fever. This was originally suggested by Golgi. There is no positive proof of the existence of such a toxin as up to date it has not been isolated. We assume that such a poison is elaborated to explain the clinical phenomena associated with the malarial paroxysm; at present this is the only possible way we can explain these phenomena.

The whole paroxysm indicates a sudden poisoning of the system followed by an elimination of some poison, whilst the rigor suggests that the whole system has been subjected to a shock. The cycle of the paroxysm, in its typical form, is embraced in the rigor, accompanied and followed by pyrexia, which are succeeded by profuse sweating and then sudden disappearance of all the pyrexial phenomena.

If in a case of, say, quartan infection, we give a full dose of quinine an hour before the fever comes on, the paroxysm occurs, but the second paroxysm is often cut short or may not occur at all. The young parasites are killed off by the quinine, which acts as a germicide, the older parasites are not affected. Theoretically, we assume that there is a toxic poison formed by the parasite which is *pyrogenetic.* The toxins are also *hæmolytic.* There are, therefore, in all probability at least two toxins, one of which is heat producing and the other destructive to the red cells. This hæmolytic action will be considered under the heading of *anæmia.* It causes a solution of the hæmoglobin in the serum. The fact that there is a malarial toxin (or toxins) is to some extent supported by the effects produced by the intravenous injection into a healthy person of the serum from the blood in a case of malarial fever during the stage of rigor. The hæmolytic action of the toxin may be seen in fresh preparations of malarial blood under the microscope. We notice that the serum acquires a darker yellow colour the longer the fresh blood is kept under observation, and the red cells become more and more embedded in the plasma.

We do not as yet really know what the toxins formed in malarial infection are. It is suggested that they are probably soluble constituents of melanin. The bone-marrow, spleen and liver, the chief organs containing the pigment, are enlarged; the toxins are dissolved out of these by the plasma and from the free circulating pigment.

The degenerative changes in the cells of nerve centres and the necrotic condition of renal epithelial cells, apart from the effects of stasis, lends support to the existence of malarial toxins. The toxins are being constantly excreted during malarial infection in large or small quantities. The parasites certainly do decrease spontaneously, and this is probably due to some germicidal agent created in the blood which acts deleteriously and specifically on the young parasites outside the red cells, in the same way that quinine does. It is considered by some authorities that the parasites attempt to paralyse the germicidal action of the serum.

Anæmia.—The first effect of malarial infection is naturally most pronounced upon the blood, in which fluid the hæmosporidia live parasitically on the red cells, and in their metabolism manufacture toxins which considerably affect all the constituents of the blood. The pigment created leads to the condition of melanæmia, which has for the last 60 years been recognised as one of the most characteristic pathological conditions in malarial infections.

The anæmia is frequently sufficient to manifest itself clinically. This is, to a large extent, the direct result of the destruction of red cells by the parasites; it is highly probable that some of the uninfected erythrocytes are likewise destroyed by the action of a soluble part of the toxins. With the decrease in the number of erythrocytes there is often a *lowering of the colour index.* The explanation generally accepted to account for this is that the bone-marrow, as a result of over-production, throws into the circulation a large number of red cells that are deficient in hæmoglobin. Usually, as the case recovers, this deficiency is made up, but in cases of malarial cachexia it may continue for months or years.

The largest destruction of red cells occurs during the early paroxysms; after a certain degree of anæmia is arrived at, the destruction becomes gradually less. It is recorded that the number of red cells may be reduced to 2,000,000 per c.mm. in four days; in one case after several attacks the reds were only 500,000 (KELSCH).

A degree of anæmia which reduces the red blood cells 20 per cent. after the first few paroxysms is very common. The anæmia, however, is not progressive, although the effects of the previous anæmia produced continues some time. After severe infections lasting some time, there is often a reduction of even 50 per cent. of the red cells, and about the same percentage loss of hæmoglobin, besides a total loss of the blood volume.

From the above statements we can readily explain the *anæmia*. Its degree depends on the number of red cells infected by parasites, the speed with which these parasites multiply, and the extent to which uninfected cells are hæmolysed; it is also to some extent dependent on the degree to which the malarial process affects the functions of the blood elaborating organs. The blood cells are not replaced as rapidly as destroyed, hence there is (within certain limits), after each series of paroxysms a greater degree of anæmia.

After the more innocent forms of malarial infection, the anæmia rapidly decreases; the same is the case after acute attacks of sub-tertian fever when promptly and properly treated. In both the simpler and more malignant forms of malarial fever, however, when improperly treated, a lasting form of anæmia arises which is so characteristic of chronic malarial infection. In this condition the parasites are still in the circulatory system. This is important epidemiologically as leading to long-lasting residual infection and relapses.

Generally there is a *marked reduction in the total amount of hæmoglobin*, especially in sub-tertian. This reduction is sometimes very speedy and may fall 25 to 40 per cent. in a few days. It is not, however, of prognostic importance, as in some serious pernicious cases it may be only slight, and in some mild cases of benign tertian, it may be considerable.

The *leucocytes* in the peripheral blood are *diminished throughout malarial infection*—there is *leucopænia*. Relatively the large mononuclear cells are increased, especially after the accés—a cyclical variation—and this is an excellent auxiliary to diagnosis in this country in the absence of malarial parasites, or in examining the blood after quinine has been administered. Sometimes in malaria there is a leucocytosis, but never in the absence of complications.

Melanæmia.—This is met with at any time during a malarial infection so long as parasites continue to develop in the blood. The best time to search for melanin in the blood is during or shortly after the paroxysm. It may also be found after the paroxysms have ceased so long as malignant crescents or tertian or quartan spherical gametes are in the circulation. Provided there are no gametes in the circulation, no melanin is to be found in the blood beyond 48 hours after the last paroxysm. This is of prognostic importance as indicating, anyhow for the time being, a cessation of the effects of the previous infection.

The hæmozoin or melanin, after it has been set free from the parasites, is contained in the large mononuclear cells (macrophages). In these cells it appears in the form of brown or brownish-black pigment, in granules, grains, clumps, or irregular blocks. This pigment is the most characteristic product of malarial infection.

The melanin set free by sporulation plays an important part in malarial fevers. The granules and blocks are rapidly taken up by the phagocytic cells—wandering and fixed leucocytes and vascular endothelium. By far the most active leucocytes in this respect are the large nononuclears, although *in vitro* polymorphonuclears may, at times, be seen to contain pigment granules.

The melanin is discharged at the commencement of a paroxysm, and this is the time to find pigment in the large mononuclears. In the spleen they take up the free pigment much more rapidly and in larger quantities. BIGNAM 3states that the pigment poisons the leucocytes the fixed ones lose their hold and are driven on to the spleen and die. They are seen to be degenerated and do not stain well. They pass along the splenic vein towards the liver—a process that occurs after some weeks. In the liver the pigment finally disappears, first losing its colour. Melanin is not soluble in acids, it is soluble in alkalies. The melanin is of lighter colour than in the parasite, being now of a dirty greyish yellow instead of brownish-black. There is abundance of melanin in the livers of small children; at 15 or 16 years of age this has disappeared (DANIELS). A month after attacks have ceased there is, in endemic malarial districts, the same amount of pigment in the liver and spleen as after a few days.

The pigment tends to be eliminated in time. While infection is going on it continues to be found in the spleen, liver and blood cells. It is never found in the parenchymatous liver cells.

The pigment is specially found in the capillaries, in much smaller quantities in the larger vessels; pigmented parasites tend to accumulate in the capillaries of the spleen, brain, liver and kidneys. "They are especially numerous where the calibre of the artery goes over suddenly into the narrow calibre of the capillary, this producing a slowing of the blood stream, as, for instance, the capillaries of the lungs, the intestinal villi, the appendices epiploicæ, the glomeruli of the kidneys, the dura-mater and the cerebral convolutions"—(KELSCH and KIENER). The internal organs in which pigment mostly accumulates are the spleen, liver and brain. Nevertheless there are exceptions to this rule, for cases are recorded where the spleen has been free from pigmented parasites and the liver laden with them, or the reverse; or where the seat of election is the brain or gastro-intestinal mucous membrane.

The reasons why some varieties of parasites are found uniformly distributed and others not, and why red cells containing pigmented parasites tend to accumulate in the capillaries of internal organs as described, has not been ascertained.

The system endeavours by slow degrees to get rid of the malarial pigment set free by the parasites. The leucocytes, especially the macrophages, and particularly the large mononuclear cells, takes up a large part of the free pigment; the remainder is deposited by these cells in the neighbourhood of perivascular lymph sheaths, and in these sheaths it is eventually seen. The lymph possibly dissolves part of this deposit; some of it, however, is deposited in the lymph glands, and may be seen in many cases of malaria in the lymph glands adjacent to the liver. It is possible that the lymph glands effect its final elimination. The actual parenchymatous cells of the liver in all probability are not concerned in the absorption and elimination of true melanin.

It will thus be seen that the pigment of malaria affects practically all the cells of the body. There is in addition a process of *necrobiosis* affecting the parenchyma of internal organs. These necrotic processes are mainly caused by stasis in the capillaries, to a less extent probably by the action of toxins. The necrotic particles are finally removed in the same way as in other diseased conditions.

Hæmosiderin.—Besides melanin manufactured by parasites in the blood, there is found another form of pigment which is yellow or ochre-coloured, called *hæmosiderin*. It is found in the spleen, liver, bone-marrow, kidneys, *pia mater*, pancreas, and thyroid gland. Rarely is it discovered in the circulating leucocytes and vascular endothelium. This pigment is derived from the hæmoglobin of red blood cells that has not been entirely eaten up by the parasites. More of it is naturally formed from the red cells infected by malignant tertian parasites, which only partly fill the red cells even when sporulating, and in segmentation a large part of the hæmoglobin of each infected erythrocyte is broken up in the plasma. Besides the hæmoglobin of infected red cells, in all probability a large number of uninfected red cells are destroyed (necrosed and broken up) by the action of a malarial hæmolytic toxin. The attacks of blackwater fever, sometimes associated with lasting malarial infection, indicates that the actual destruction of red blood cells is at times enormous. We are as yet unable to account for this occurrence; the statement that the toxin of malaria brings about hæmolysis is hypothetical. It may in part be due to autolysins. " Whether the fragments of the red cells are taken up as such by the parenchymatous cells and transformed into this ochre-coloured pigment, or whether only the hæmoglobin of these fragments infiltrates the cells in a dissolved condition and is there precipitated in this form, is a question which in our opinion may be answered by the assertion that both probably occur. The further fate of this pigment is only partly known." *

It is considered that the liver cells metabolise their share of this pigment into bile, which would explain the large discharge of bile met with during malarial paroxysms. The spleen sends its share of the pigment to the liver.

The main effects of malarial infection—pyrexia, anæmia and melanæmia—are now easy of explanation.

Causes of malarial pyrexia.—The pyrexial phenomena of malarial paroxysms has been satisfactorily explained, but not with the same degree of precision as the anæmia and melanæmia.

The parasite in its growth on red cells produces a pyrogenetic material which is set free when the red cells burst during sporulation and is capable of disturbing the thermotaxic mechanism, probably mainly by increasing thermogenesis and to a less extent by lessening thermolysis, while within the red cells this pyrogenous material cannot be set free in the plasma and does not affect the temperature. It is only when it is set free after sporulation and reaching the special nerve centres connected with heat regulation that this influence is exerted.

The toxins of malarial infection appear to have a special affinity for the nervous system, and this explains many of the clinical phenomena of malarial fevers and their sequelæ.

The entire paroxysm of malaria is in all probability due to the effect of a poison on the nervous system. The paroxysm is the clinical manifestation of the reaction of the nervous system to the malarial toxin circulating in the blood—a regular intoxication. Many of the nervous symptoms seen in malarial fevers show us that all parts of the nervous system share the effects of this intoxication, which is first manifest in its action on the vaso-motor centres. In the cerebrum we have every degree of effect from slight stupor to coma, from minor depression to active delirium ; headache more or less is associated with every paroxysm ; neuralgia often occurs, especially in the second and third divisions of the fifth cranial nerve.

Effects of simultaneous sporulation of parasites.—The time of commencement of the fever paroxysm coincides with that of sporulation of the parasites in the blood. This simple biological fact, discovered by Golgi, has swept away volumes of unfounded theory.

We should not, however, push this question of equal ages and simultaneous sporulation of all the parasites of an original stock of sporozoites too far. Were the hundreds of millions of parasites necessary to give rise to a malarial paroxysm of identically the same age to a

* Marchiafava and Bignami, *Twentieth Century of Medicine*, Vol. XIX.

moment, then every field of a slide containing parasites would give precisely the same picture, whereas the fact is we never see such fields (except occasionally in malignant tertian in which sporulation goes on in internal organs) ; there is, as a rule, several hours between the ages of the parasites seen on every slide, even in those of quartan, in which we have the nearest approach to simultaneous sporulation. We have mentioned malignant tertian as an exception, but a close examination of any slide shows that in reality it is not so, for we frequently see in it very young unpigmented amœboid parasites resting on the red cell, fully formed rings and egg-shaped pigmented forms within the red cells, the last named being the highest stage of the evolution of the parasite ordinarily seen in the peripheral blood.

Notwithstanding the differences in the ages of these individual parasites it is necessary to consider them all as of one generation. One should remember that the vast majority of cases of malarial infection are not the result of the single bite of an infected anopheline. Such infection usually results either from several bites of the same anopheline, or the bites of several anophelines one after another ; that these bites chiefly occur during the night, and that many hours may elapse between the earliest and latest bites giving rise to the infection. It is reasonable to suppose that the ages of the schizonts developing from the sporozoites inoculated during these various bites would differ by many hours, and that there would be a corresponding difference in the times at which they would reach maturity, that is, sporulate. One believes this to be the explanation of the cause of the varying lengths of the paroxysm met with in infections by different species of malarial parasites.

With each bite of an infected anopheline there are certainly hundreds, probably often thousands, of sporozoites injected, and if the bites occurred at, let us suppose, intervals of an hour, and four bites took place, we would have four groups of sporozoites producing schizonts which would have a difference of one, two, three or four hours in their ages. The difference from the bites of one night may be much greater than this, as when infected anophelines bite just after going to bed, say, at 10 or 11 P.M., and again in the early hours of the morning. This, however, is not the entire explanation, and as in all other animal forms, the struggle for existence is a potential factor affecting the duration of evolution. There is a corresponding difference in the period of the evolution of sporozoites from the impregnated gamete. As the result of a single bite an anopheline may suck into her stomach hundreds of crescents or spherical gametes. Many of these are not sufficiently mature to develop further, but of those that are, in all probability the large majority procced to further development, the microgamete of exflagellated males impregnate all fully developed macrogametes, the resulting vermicules finding their way through the epithelial cells and resting in the stomach walls as zygotes.* It is probable that this process goes on in the stomach for some hours at least, although beginning almost as soon as the blood reaches it. A few days later another feed of blood from a malarial person occurs. At the end of six days from the original meal of malarial blood, it will be seen that the zygotes in the stomach walls are of various sizes, that some have already developed sporozoites, whilst others will not do so for a few days. All have developed under the same conditions. The analogy holds good regarding the asexual cycle of these parasites in the human blood—it is highly improbable that of the millions present during a paroxysm, even when they are the result of a single bite, will mature at identically the same moment.

Whatever be the explanation, we know as a fact that the individuals of one generation never do sporulate at the same moment, but do so one after another at brief intervals, and as a result each form of parasite produces its own special clinical feature in causing the paroxysm to last for from a few hours in typical quartan to 30 or 40 hours in typical malignant tertian paroxysms. "If the innumerable sporulation forms, similarly to a volley of a large number of guns, would burst in a moment and throw their contents into the blood-stream, it is very likely that a much shorter but also a much more violent paroxysm would be the result, but as it actually is, the sporulation takes place, after the manner of a rapid fire, and continues the fever paroxysm through a series of hours"—(MANNABERG).

That toxic bodies are set free at the moment of bursting of the red cells and setting free the merozoites is extremely probable. The toxicity of the urine after a paroxysm is higher than normal, although the experiments hitherto conducted to prove this must be accepted with some reservation. It is assumed that the toxin gives rise to the paroxysms by its effects on the vaso-motor centres and thermotaxic mechanism. It is comparable in this respect to the toxins manufactered by bacteria in septic and pyæmic states; indeed in the latter we have as yet no adequate explanation for the periodical return of fever, etc., whereas in malarial fever such an explanation is presented in the biological evolution of the parasite with each paroxysm of fever. We are aware that some high authorities explain the periodicity of the paroxysms to an intermittent activity of the phagocytes; and that in order to explain the various types of fever they presuppose a greater or less activity on the part of the parasites in different countries, together with a difference in the reaction of the human organism. The known biological facts in regard to the parasites are, however, so intimately connected with the clinical phenomena of a paroxysm, that one feels forced to accept the view originally propounded by Golgi—that the paroxysm is due to the sporulation of the parasites more or less simultaneously.

* Several hundred zygotes may mature to sporoblasts in the stomach wall of one anopheline. GRASSI has counted as many as 500 in one mosquito, and as each sporoblast may give rise to about 10,000 sporozoites, one mosquito may at the same time set free five millions of sporozoites into its body cavity and salivary glands.

There is practically no system of organs in the body that is not at times affected in malignant tertian fever. The implication of internal organs is in all probability mostly due to accumulation of parasites, although the action of the toxins liberated *in loco* can also reasonably be incriminated in this respect.

Observations have shown that the parasites of malaria are not equally distributed in the circulatory system. In quartan fever the parasites are uniformly distributed in the peripheral circulation and internal organs (spleen, bone-marrow, brain, etc.) ; in simple tertian the proportion is greater in the internal organs, and in malignant tertian much greater.

Enlargement of the spleen.—This is an invariable accompaniment of the malarial paroxysm, though in the earlier paroxysms it may not be sufficient to be manifest by palpation. It is always appreciable by physical examination whenever malarial paroxysms have continued for a week. This opinion one has arrived at after examining many thousands of cases.

The longer the continuance of the paroxysms, the more repeated the fresh infections, and the more lasting the relapses, the greater is the hypertrophy and the induration of the spleen. With the earlier paroxysms the spleen is soft, retains its normal shape, has a sharp anterior margin, and on deep inspiration extends only slightly, if at all, below the left costal margin. Pressure from behind forwards of the left lower false ribs may often render a sightly enlarged spleen manifest by palpation. The increase in size of the spleen with each paroxysm and its partial recession during the intervals, may often be distinctly recognised in hospital cases.

The extent of splenic hypertrophy has a distinct relation to the length of the infection. In comparatively recent infection there is seldom any considerable hypertrophy, whereas in chronic infections the spleen is more often considerably, sometimes enormously, enlarged.

The enlargement of the spleen of recent origin does not as a rule give rise to pain that is complained of, though in many cases, it is tender on palpation. Sometimes, however, pain is complained of and may be of a sharp shooting character similar to that of the first stage of acute pleurisy. This is in some cases probably due to a perisplenitis, in others to stretching of the capsule, in others again to localised inflammation of the splenic parenchyma. One has seen three cases of this last named condition ending in suppuration, two of which were operated on and drained successfully, the third, a boy of about 10 years suffering also from cancrum oris of the left cheek, died from the general effects of malarial cachexia and sepsis combined. The largest malarial spleens are naturally found in endemic malarial centres where the inhabitants are constantly exposed to re-infections during the malarial season, and suffer from relapses during the non-malarial part of the year. Should these patients not succumb and eventually acquire a relative immunity, the spleen may once more disappear beneath the left costal arch, though it is more likely that some small degree of enlargement will be permanent.

The enlargement of the spleen in chronic malarial infection may be so great as to give rise to considerable tension of the capsule; in this condition rupture of the spleen is liable to follow slight injuries or falls. Following such rupture there is extensive hæmorrhagic extravasation into the abdominal cavity and usually rapid death. Death may not however be immediate. One has recorded two cases where the victims of traumatic rupture of malarial spleens walked home and died after their accidents.*

B.—Pathological Anatomy.

Morbid anatomy of enlarged spleen in malaria.—This organ is always enlarged but to a varying degree. Its consistency is lessened, sometimes to the extent of being diffluent. In colour it varies from dark brown or chocolate brown to a slaty or black colour; this hue being usually diffuse, the section is of a dark greyish brown, and the non-pigmented malpighian bodies stand out clearly. The capsule in acute cases is thin and easily torn; in chronic cases it may be thick and firm.

Microscopically the venous sinuses are seen to be dilated, sometimes markedly so, when they may give rise to hæmorrhages. The pulp is more or less packed with red cells, mostly infected. The pigment is chiefly contained in macrophages, though a small amount may be free. The phagocytes usually stain well, though many are seen from the defective staining of the nuclei to be degenerating. They contain melanin granules, parasites, the remains of red cells, and particles of hæmosiderin. Occasionally the spleen contains few parasites and little pigment. Stasis in the capillaries is often met with, as are also disseminated necrotic patches resulting from these thromboses.

Liver.—The liver is usually enlarged; its colour on the surface varies from a steel-blue or olive grey to chocolate, or even deep brownish black. The capillaries of the portal and hepatic veins, and the branches of the hepatic artery, are microscopically seen to be packed with parasites. The branches of the portal vein contain splenic macrophages, which may be sufficient in number to block the capillaries—macrophages are not seen in the branches of the hepatic veins. The hepatic cells are enlarged, frequently contain hæmosiderin, rarely melanin, sometimes the remains of red cells (Bignami). The endothelial cells of capillaries are often swollen; this swelling may even include the vessels, and these cells may contain melanin, as may also the swollen Kupffer's cells. Occasionally microscopic necrotic patches are seen from thromboses due to leucocytes. "Collections of small cells are not infrequently found

* Hehir and Gribble, *Medical Jurisprudence for India*, 5th Ed., p. 183 *et seq.*

in the tissue around the portal vessels, and this may be the earlier stage of a succeeding cirrhosis"—(MANNABERG). There is often some hyperæmia to which, with the infiltration with pigment, the enlargement is due.

Bone-marrow.—The *bone-marrow* is soft, almost diffluent, of a brownish red colour, its vessels contain numerous schizonts and sporulating parasites, gametes, macrophages are numerous, often partially degenerated; the *nucleated* erythrocytes seen, sometimes in large numbers, do not contain parasites.

Nervous system.—Occlusion of the circulation in a large number of capillaries of the central nervous system explains most of the functional disturbances met with. The effects of *capillary hæmorrhages* resulting from thrombosis is difficult to separate from those of thrombosis itself.

Brain and spinal cord.—The brain cortex is often markedly melanotic from the accumulation of pigmented parasites in the red cells. The dark coloration is nearly always visible to the naked eye. The grey and white matter of the cord is affected in the same way.

Microscopically the *pigment* is usually seen to be uniformly distributed in the brain, but it may be scattered. When uniformly distributed the position of the pigment maps out the capillary blood vessels. The pigment is contained in red cells within the capillaries. Sections show that the infected red cells are glued to the endothelial walls, and the healthy ones in the middle. Pigment is, however, also contained in the large mononuclears and in the endothelial cells; the swollen state of the latter cells helps to occlude the vessels and disturb the circulation. Even the smaller arterioles are sometimes found to be blocked by the infected red cells. "More rarely we find other thrombi caused by the accumulation of free pigment, melaniferous leucocytes, and spores."

Schizonts seen in the brain capillaries are mostly near the stage of segmentation, "most of them in the act of sporulation. Crescents occasionally occur in great numbers"—(MANNABERG).

Hæmorrhages of different kinds are often met with in cerebral pernicious attacks—they are usually punctiform and often numerous. These occur mostly in the white matter of the brain and cord, and in the strand of tissue between the white and grey matter—(BIGNAMI). One has, however personally, repeatedly found these punctiform hæmorrhages in the cortical substance of the brain.

C.—RELAPSES AND RE-INFECTIONS.

Definitions of relapses and re-infections.—By a *relapse* we mean the recurrence of a malarial paroxysm or series of paroxysms sometimes weeks, or even months, after an antecedent attack of malarial fever, without the intervention of a fresh infection—it is the re-awakening of the clinical phenomena by malarial parasites that have remained dormant in the body from a previous period. They are quite unconnected with re-infections. By *re-infection* we mean a new infection of the blood by malarial parasites through anophelines, after the system has, by treatment or spontaneously, got rid of all parasites by which it was previously invaded.

Relapses must in India be looked upon as one of the ordinary occurrences of malarial infection. It is now fully recognised that relapses may, by appropriate and prolonged administration of quinine, be entirely eliminated in any individual case, and in groups of men under control and discipline. Without such treatment malarial fevers, especially in malarial districts, in the majority of cases are followed by relapses. For the few millions of cases that are brought under treatment in hospitals, jails, asylums, and the men of the Indian Army, there are tens of millions of cases that are never recorded and comparatively few of which ever get quinine. These occur chiefly amongst the impoverished labourers and ryots, whose condition of nutrition and lowered resistance render them specially prone to relapses. It is the cases of relapse occurring during non-malarial seasons that serve to maintain the breed of malarial parasites throughout the year; from them the young broods of anophelines at the early stage of the rains begin afresh the process of universal infection of human beings. Hence we can readily see the very important rôle played by man in the perpetuation of malaria in this country. There are probably thousands of millions of anophelines in every endemic malarial district; there are certainly thousands of them to every case of malarial infection. From this we can see how little is the effect of reducing anophelines, even if we could do so by one half, so long as there are these millions of cases of untreated malaria for the other half to feed upon. Hence all malariologists in India insist that it is of more importance to endeavour to eliminate malaria by proper treatment than to endeavour to exterminate anophelines. Both tasks are at present equally impossible as far as this country as a whole is concerned. It is not so however with comparatively small districts with isolated malarial foci, in which both measures, the universal employment of quinine in malarial infection and destruction of breeding places within measurable distances of habitations, will go far towards reducing the endemicity. There are certain large districts also in which these measures may be employed with partial success.

In a malarial district during the malarial season, when fresh infections are constantly liable to occur, it is practically impossible to decide whether a particular case is one of re-infection or relapse. A careful anamnesis of each case, with examination of the blood, and a history of the course of the infection (if any), would probably give us information upon which we could draw inferences as to whether it was a re-infection or a relapse, but such deductions would not be scientifically reliable. The only positive indication of a re-infection would be a record to the effect that the preceding attack was caused by a species of parasite different from the one discovered in the blood during the attack under investigation. Relapses are evident also when malarial paroxysms occur in a non-malarial locality in a person who has recently left a malarial place, in which latter he had suffered from malarial fever.

Relapses occur after all forms of malarial fever, but are said to be much more common after malignant tertian, and more obstinate to treatment after quartan. One has had the opportunity of inquiring into the relapses occurring in several non-malarial places in troops returning from intensely malarial localities, especially in Shillong and Lansdowne. Detachments sent to the Bhutan Frontier at the end of autumn annually from the former station returned to a man with greatly enlarged spleens, anæmia, and crescents in their blood. Amongst the 178 cases investigated there was not a single one of either benign tertian or quartan infection; in all there were relapses and during the relapses malignant tertian amœboid forms and rings only were found and these were invariably followed by crescents. During three years in Lansdowne one has inquired into 161 cases of relapse and found crescents in 8 only, in one of which there was mixed infection with benign tertian parasites, the other 153 were all simple tertian. Of the 161 relapses, 130 were amongst Gurkhas (recruits and returned furlough men) who had passed through the Nepaul Terai late in autumn and the beginning of winter, 30 were in Garhwali furlough men—two of the 8 malignant tertians were in the latter. Recently one has ascertained that 35 per cent. of the relapses occurring in troops quartered in the Fort at Delhi were malignant tertian, and 24 per cent. of those in Meerut.

My experience has been that there is no regularity in the time of the recurrence of relapses, and that they tend to become more and more remote from one another and the paroxysms of less severity. This is particularly the case in patients who are only partially treated by quinine after the attacks are over, as occurs in most regimental hospitals. Relapses can be completely prevented in the vast majority of cases by the continued use of quinine in the manner laid down under the heading of CURATIVE USE OF QUININE IN PART III.

Blood examinations during relapses are always positive when quinine has not been given before the examination, and there is apparently no appreciable difference in the actual number of parasites in the blood during the different relapses. For several days following the relapse, even when quinine is being administered, occasional parasites are to be found, and for about two days, after the paroxysms have ceased, pigmented large mononuclears. In relapses of the more innocent intermittents spherical gametes occur after the fever in the same way that they do after the original attack; the same holds good regarding crescents in malignant tertian.

Re-infection in malarial regions is specially common. It would appear that for a time at least after the original attack the susceptibility to re-infection is increased, although after a series of re-infections this susceptibility appears to be lessened. The re-infection may be of the same species of parasites as the former attacks, or by other species, showing that the individual species bring about no immunity against re-infection.

Parthenogenesis.—Regarding many of the points mentioned we find analogies in the process of development of sporozoites in *Coccidia* (to which in its entire life-history, sexual and asexual, the malarial parasite is identical), whilst as regards relapses it is somewhat probable that gametes, which do not leave the blood, collect in internal organs and subsequently as "indifferent" parasites, are capable of taking up the process of schizogony, resulting in the invasion of red blood corpuscles by the spores so formed. There are several instances of such parthenogenesis in the Protozoa, notably in *Coccidia and Trypanosomata.* "The stimulus to the renewed activity of the parasite which brings about relapse is perhaps supplied by some external cause such as a chill, which lowers the resistance of the host. The parthenogenesis of the female sporonts, as described by SCHAUDINN, is essentially similar to what occurs in trypanosomes, and consists in the gametocyte being set back into the indifferent or schizont form, after which it sporulates in the usual endogenous manner."*

Probable explanation of relapses.—In the case of relapses we may suppose that the male gametes gradually die out with all the weaker schizonts, whilst the hardier female gametes recede to some region of the circulation, still to be discovered, and adapts herself to the altered conditions now imposed upon her, to carry on the species at some future date. One has on three occasions obtained "crescents" from spleen smears of bodies of patients who had months previously suffered from malignant tertian ague, and died from some other disease. There was no characteristic observable to distinguish these from ordinary crescents in circulating peripheral blood, except that they were uniformly crescentic and all were of the one female sex. It is possible that gametes are capable of forming anti-bodies to defend themselves against attacks of white cells, the serum, and the action of quinine.

The female malarial gamete is, like the female gamete in the Coccidia, the most resistant phase of the malarial parasite, and it is possible that this resistance grows until it attains a maximum. It is possible also that she acquires an immunity to deleterious agencies, natural or artificial, in the circulation, just as we know trypanosomes of various animals in laboratories eventually acquire an immunity to the action of atoxyl, trypanred, fuchsin, etc.

Without treatment by quinine, malarial fevers occurring in the inhabitants of malarial districts, tend to become chronic; this is the ordinary course. Therefore the vast majority of the cases of malarial

* MINCHIN in ALLBUTT and ROLLESTON'S *System of Medicine*, Vol. II, Part II, p. 79.

infection in this country (who may be considered never to take quinine) are cases of chronic malarial infection. One would again emphasise the fact that when malarial fevers are properly treated with quinine, relapses occur in but a small percentage of cases.

It is this absence of quinine treatment that causes such a large number of cases of infection by the more innocent parasites to become chronic; it is well known that relapses of the ordinary intermittent fevers are readily prevented by the use of quinine—it is only exceptionally that such cases under adequate quinine therapy become chronic, and of the two forms, quartan is said to be the more obstinate to such treatment. One has no hesitation in stating that some of the most serious forms of chronic malarial infection and malarial cachexia met with in malarial districts are due to benign tertian or quartan parasites, notwithstanding the generally accepted statement that such cases are mostly limited to cases of crescent fever (malignant tertian).

When properly treated by quinine most of the cases of malaria do not relapse, nevertheless the drug often fails to eradicate all the parasites from the blood. It would appear as if quinine was in such cases incapable of attacking the parasites ensconced in the vascular recesses of internal organs. This is one of the reasons why the proportion of cases of relapses is greater in malignant tertian than in benign tertian and quartan in which the parasites are usually in the assailable situation of the peripheral circulation.

The cases of chronic malarial infection most frequently occur from the end of autumn onwards. In the case of the native soldier brought to hospital at this time, he is placed under quinine treatment and discharged convalescent. He returns in a few weeks with fresh paroxysms, and this goes on. So long as taking quinine the paroxysms are checked. This may continue during the winter and often well into spring. He may or may not be sent home on sick furlough more or less impregnated with malaria. At home he gradually gets completely well, and may remain so, or he suffers from a pernicious attack from which he may or may not recover. This is not the ordinary course at the present day as most native soldiers are obliged to attend hospital regularly for their dose of quinine, until the medical officer is assured by constant blood examination that the parasites are eradicated, and the same remark applies to jails. But what has been said applies to a very large proportion of the cases treated as out-patients in our Indian civil hospitals.

There is still much in connection with the life-history of malarial parasites that we are unacquainted with, and one of the most difficult problems is the exact pathogenetic relations of relapses. We have been accustomed to believe that malarial parasites, like all other sporozoa, after several generations of asexual life, tend to exhaust themselves, but the recurrence of malarial fever for years in persons who have left the malarious locality in which they acquired malarial infection, and lived in non-malarious places, that is, without the possibility of re-infection, indicates that such asexual multiplication may continue indefinitely. In Lansdowne (5,600 feet) where there is no initial malaria, one has seen cases of such relapses going on for at least two years. There is undoubted evidence that such relapses may go on for a much longer period. Recently Dr. ANTON BRIENL, of the Liverpool School of Tropical Medicine, has demonstrated malarial parasites in the blood of a patient, who had not been in any malarious place *for seven years*. There is probably much more in relapses than is accounted for on the simple explanation of parthenogenesis and a return of female gametes to "indifferent" forms.

D.—LATENT AND MASKED OR LARVAL MALARIA.

Latent malarial infection.—By this is meant cases of malarial infection in which no clinical manifestations of malaria are presented in patients, who have died from some other malady. The lesions produced in these cases as seen after death are largely confined to the spleen and liver. Malarial infection may be *latent* until something lowers the physiological resistance and causes malarial parasites to multiply in the blood. For this reason in India we sometimes find it coming on during or after an attack of pneumonia, complicated dysentery or enteric fever, after parturition, etc.

When malarial fevers subside, either spontaneously or under quinine, the parasites as a rule vanish from the peripheral circulation. If quinine is not kept up this disappearance is only temporary. After some time, varying from weeks to months, the parasites reappear in the peripheral blood with the occurrence of a relapse of pyrexial phenomena. It selects certain organs or tissues in which to remain in a latent form. We do not as yet know what are its characters in these organs or what changes of structure, if any, it undergoes in them, nor do we know precisely the conditions which favour its multiplication and reappearance. Any lowering of the vital processes, however, lessens the prohibitive power of the system to prevent multiplication; a system in a state of complete physiological resistance and the action of quinine favour latency.

In latent malarial infection prior to clinical manifestations malarial hæmospöridia are going through their life-cycle in the spleen and can be demonstrated in sections of this organ after death. Were such latent infection suspected, malarial parasites would be found in aspirated splenic blood. CRAIG found that out of 1,267 cases of malaria, in which parasites were demonstrated in the peripheral blood, 395 or about 32 per cent. showed either "latent" or "masked infection."

Masked or larval malarial infection.—By this we mean a condition in which the symptoms of malarial infection are hidden by those of some associated disease, or in which the symptoms are so atypical as not to be recognised. Of the 395 cases mentioned above 275 were æstivo-autumnal infections, showing that the æstivo-autumnal parasite is connected most frequently with latent and masked malaria. Examinations of the blood in these cases showed the parasite in all stages of development, but always in small numbers. Of the 395 cases 277 were latent infections, that is, malarial parasites in the blood without symptoms, while 118 were masked infections, most of them being in patients suffering from diseases which masked the malarial symptoms. Chronic dysentery, chronic diarrhœa, pulmonary tuberculosis, and amœbic dysentery, were the diseases which most often masked the malarial infection

E.—Malarial Cachexia.

Clinical characters.—Repeated attacks of malarial infection, improperly treated or not treated at all, are liable to culminate in the condition known as *malarial cachexia*, the chief *symptoms* of which are some anæmia with great enlargement of the spleen. It occurs mostly in endemic malarial districts and especially follows malignant tertian, although it is by no means infrequent after neglected simple tertian and even after quartan. It may occur after latent and masked malarial infections that have gone untreated and unrecognised.

Anæmia and enlargement of the spleen.—The *anæmia* is of the secondary type, the erythrocytes reduced to 2,000,000 per c.m.m. or fewer: and there is an increase of the large mononuclears. This latter with the *splenic enlargement* may be the only remaining specific indications of malaria. The spleen is sometimes very large, almost filling the whole abdominal cavity; usually extending to close to the crest of the ilium below, half way to the umbilicus in front—that is from 3 to 4 or 5 inches below the left costal arch. It is moderately firm on palpation and not painful.

The skin.—The *skin* of the European suffering from malarial cachexia acquires a peculiar yellowish or tawny hue, and the mucous membranes are pale In natives the skin of the face becomes darker, and this may be in patches or general.

The associated symptoms are gradually increasing weakness, dyspnœa, loss of appetite, and diarrhœa; there is no real emaciation such as is seen in kala-azar. There are periodical outbursts of malarial fever and during the intervals the temperature is normal. The parasites are found in the blood during these pyrexial attacks and may completely disappear between them This is one of the most frequent morbid conditions seen in the children of endemic malarial districts. Of 3,884 children between 0 and 10 years of age recently examined in a large endemically malarious district one found that 2,330 or about 60 per cent. had varying degrees of enlargement of the spleen; amongst the spleen cases there were 98 cases or 4·26 per cent. of malarial cachexia. The average malarial index of the 3,884 was about 40 per cent.

Pathogenesis of malarial cachexia.—In malarial cachexia the pathological alterations are connected mainly with changes in certain organs, and, in this respect, are separated from pathological effects of acute malarial infection which are to a large extent confined to alterations in the blood.

As we have seen in the early attacks of malaria hundreds of millions of red blood corpuscles are destroyed by the suction of the parasite. This occurs also in every repeated attack. The restoration of the normal equilibrium in red cells has to be effected by the blood-forming organs. These same organs during malarial infection are busily occupied in removing the melanin and the débris of hæmoglobin set free during sporulation. The function of removal falls chiefly on the liver, but is also shared by the spleen, kidneys, lymph glands and mucous membranes of the intestines.

So long as the bone-marrow and the organs named are capable of meeting the demands of the organism and of restoring the loss effected by the parasites, so long will there be no cachexia. When, however, anything interferes with the functional or structural integrity of these organs, then the clinical phenomena of malarial cachexia manifest themselves—in the case of functional disturbance only the condition will be temporary, in the case of structural alterations, if these are at all serious, the condition will be permanent. When the tissues of the bone-marrow, spleen and liver become functionally inefficient, then malarial cachexia develops. In general terms it may be said that clinically this cachexia consists of symptoms connected with anæmia, hydræmia, and a surcharging of the organs with pigment. The functions of the organs of the body are already at a low ebb, and the morbid state of the organs prevents speedy repair.

Malarial cachectics are in a high state of susceptibility to other infective and inflammatory diseases, from which they frequently suffer. Hence we should not attribute every morbid state observed to the influence of malarial infection in these cases.

Malarial marasmus.—Bazar or village children in this condition frequently die from a genuine *malarial marasmus*, or from some intercurrent disease, especially diarrhœa. Adults may suffer from this state for years, during which time they usually suffer also from various intercurrent diseases.

Non-parasitic post-malarial fever.—The condition of *non-parasitic post-malarial* fever is now a well recognised clinical entity in some of these cases. It is certainly unconnected with present malarial infection, for parasites are not found in the blood, and the condition is in no way affected by quinine. In many cases there is no discoverable complication. A number of these are probably due to pathological processes caused by the preceding malarial infection such as fibrotic hyperplasia in the liver and spleen, necrotic processes from previous thrombosis, etc.

F.—Diagnosis of Malarial Cachexia from Kala-azar.

The association of the Leishman-Donovan body with a clinical condition very similar to that of malarial cachexia, has necessitated a closer investigation into the two groups of similar cases, and the outcome of all recent observations is the conclusion that a certain number of cases formerly called malarial cachexia were in reality kala-azar.

Kala-azar is characterised by an irregular remittent fever, loss of body weight and emaciation, a peculiar cachexia associated with a darkening of the complexion, enlargement of the liver and spleen, often diarrhœa, sweating at night and well marked secondary anæmia. The average blood count may be stated to be about 2,400,000 red cells, 1,000 to 2,000 leucocytes—there is a relative increase of large mononuclears, but this is not constant; the hæmoglobin averages 48 per cent. The parasite may be recovered from the peripheral circulation by examination of the blood by centrifugalising; it may also be got by puncturing either spleen or liver; abstraction of blood and cells from the latter organ is less dangerous than by puncture of spleen. A full sized hypodermic needle should be used and the precautions given in Part III strictly adhered to. Quinine has no effect on the temperature of kala-azar. Apparent cures do sometimes occur spontaneously. The mortality is about 90 per cent. Kala-azar is not confined to certain parts of India; it has been seen sporadically in Tunis, Algiers, Obdarman, China, etc. In its epidemic form it is now limited to Assam.

The parasite has been found in most organs: bone-marrow is a favourite seat of election; ulcers of intestines; lungs; testes; but they are most numerous in liver and spleen. It is a general blood infection

Patton has recently shown that the parasite of kala-azar may in a large percentage of cases be recovered from centrifugalised blood, by which process the leucocytes containing the parasite may readily be removed, stained, and examined as ordinary smears.

It appears to attach itself to houses, and may be considered a domestic disease, which favours the view that it is communicated to man through some insect. So far no treatment has been of any avail. These parasites are entirely intra-cellular, and are found chiefly in the large mononuclear leucocytes on smears, and in the endothelial cells of the vessels of the liver and spleen *post-mortem*. The parasites are very small but typical, from 1 to 2 microns in length, are round or oval, possess a large and a small nucleus not unlike the micronucleus and macronucleus of a trypanosome; they have been cultivated *in vitro* in citrated blood by Leonard Rogers, and develop into flagellated organisms which have most of the characters of *herpetomonads*: their development into the herpetomonad form has been followed in the stomach of the bed bug (*Cimex rotundatus*) by Patton. *Leishmania-donovani* has likewise been successfully inoculated into dogs in this country and in Algiers.

The evidence is rapidly growing that this parasite plays an important part in the fevers of this country.

G.—Spontaneous Cure.

It is within the experience of all medical men in India that in healthy persons a small infection of malarial parasites may be, and often is, completely thrown off. In all probability a similar infection, when the physiological resistance is reduced from any cause, would bring about definite symptoms of malarial infection.

Here (Lansdowne, 5,600 feet) where no fresh infection can arise as no anophelines exist, one has frequently tested this. Even pernicious cases may recover spontaneously : " several such cases have been reported by Torti. "*

Of 987 native children examined on hill stations (height 5,000 to 7,400 feet), in which no initial malaria existed, one found that there were 101 or about 10 per cent. with enlargement of the spleen. None of these children had been under quinine treatment. They had practically all been on the plains during the preceding 12 months and were drawn from the same classes as the 3,884 mentioned on p. 124—they were the children of native followers of European Troops regiments. In the 3,884 the spleen rate was 60 per cent., in the hills' children 10 per cent., therefore 50 per cent. of the splenic enlargements (in the absence of re-infections) disappeared spontaneously within 12 months. The endemic index in the 3,884 children was about 40 per cent., that of the hills' children 5 per cent.

The human body undoubtedly possesses natural means of destroying the malarial parasite. The chief agency by which this is brought about is the large mononuculear leucocytes and to a much less extent the polymorphonuclears. The leucocytes effect the destruction of some of the parasites during the febrile paroxysm, and also ingest the disintegrated forms after the conclusion of the febrile attacks. When the nutrition of the body is perfect this and other defensive natural processes are considerably helped, whereas when the vitality is lowered from any cause spontaneous cure is hindered.

H.—Malaria in Relation to other Infectious Diseases.

Liability to secondary infections.—While what seems reasonable is not necessarily scientifically accurate, it would appear that an organism whose physiological resistance is considerably reduced, and whose blood elaborating and eliminating organs are functionally defective (as is the case in malarial infection of any duration), is in a highly susceptible condition to acquire secondary infections. Such infections are frequently associated with malaria.

Malaria and enteric fever.—These two conditions do not exclude one another. There are numerous districts, towns and cantonments

* Ross and Stephens in Nothnagel's *Encyclopædia of Practical Medicine*, Article *Malaria*, p. 446.

in India where both are endemic, and cases are often seen in which the double infection has taken place. In one's own experience one has found this combination in Lucknow, Benares, Delhi, Peshawar, Hyderabad (Deccan), Bakloh and Lahore. In rural endemic malarial districts enteric fever is rarely seen, and this may have something to do with the tradition that was for a time current to the effect that these diseases antagonised each other. Each form of infection is quite specific, and the one in no way minimises the other. The literature of *post-mortems* in our large Indian hospitals confirms the statement that the two diseases may co-operate in bringing about a fatal termination.

Both diseases may run their course simultaneously. All experienced medical officers in India have met with such cases, and there are instances on record in which positive blood examinations of malarial parasites and (in a few cases) positive cultures of Eberth's bacillus from the blood, or Widal's reaction (in a fairly large number) in the same cases. During the last seven months one has had two such cases under observation. My personal experience has been that the malarial paroxysms precede the enteric symptoms, which latter are to some extent masked by the dual infection. Again sometimes the malaria is masked by the enteric symptoms; frequently the malaria parasites disappear from the blood for a time during the course of the enteric, and reappear during convalescence; cases of enteric fever are recorded in which malarial paroxysms were made known by irregularities in the fever occurring periodically with marked anæmia. In this condition of dual infection it is quite impossible to make a correct diagnosis from the clinical phenomena alone. A positive diagnosis of either form of infection is also very difficult from clinical manifestations alone. Cases of severe malignant tertian with a continued or sub-continued temperature frequently run a course that closely resembles enteric; and the latter disease may often begin with a cold stage and intermittent rises of temperature and sweating, or have a remittent character, or assume this character from secondary infection during the later stages.

We in India recognise that this dual infection is clinically met with, and by a number of experienced men the original term applied to it by WOODWARD though scientifically inappropriate, *typho-malarial fever*, is still used.

Malaria and dysentery.—These two infections often occur in the same district endemically, and it by no means infrequently happens, especially in the later stages of malarial infection, that the two run their course in the same person concurrently. The paroxysms of malarial fever aggravate the dysenteric symptoms and the latter may then obscure the former. A positive serum reaction to dysentery bacilli in bacillary dysentery, or on examination of the fæces for *Entamœba histolytica* in endemic dysentery, and the blood for malarial parasites will both in such a case be positive.

Malaria and scurvy.—There are few of our Indian Frontier campaigns in which these two conditions are not met with in the same troops, the one aggravating the other. The scurvy comes on after some months' exposure to hardship and some physiological deficiency in the diet.

Malaria and beri-beri.—One has been told by several practitioners of the Malay Straits, China, and Formosa that they have seen both these conditions simultaneously in the same persons, but one has no personal experience of this combination in this country.

Malaria and relapsing fever.—*Malaria* has been found in association with *relapsing fever*, both malarial parasites, and the *Spirochæta obermeieri* being found in the blood of the same patient at the same time.

Malaria and syphilis.—Malaria and syphilis may not only occur in the same person but the one disease considerably aggravates the other, and unless the malaria is promptly treated the dual infection is a very serious matter for the patient. One has on three occasions during the last four years abstracted *Treponema pallida* from the enlarged lymphatic glands of patients suffering from syphilis in whose blood malarial parasites were found.

Tuberculosis and malaria.—It was at one time considered that malaria was antagonistic to tubercular infection in this country. Ten years' practice in a large hospital has convinced me that they aggravate one another. A frequent history in pulmonary tulerculosis is that it has been preceded by series of malarial paroxysms or a number of relapses and rallies. Once the hectic stage is reached the tubercular factor dominates, and it is then rare (in this combined infection) to find malarial parasites in the blood.

Septic infection and malaria.—Septic infection and malaria are frequently found together in the same patient both during the malarious and non-malarious seasons, especially in the later stages of malarial infection and in malarial cachectics.

Tropical hepatic abscess and malaria.—In malarious districts, which are often also districts where endemic dysentery is prevalent, tropical hepatic abscess and malaria are sometimes met with simultaneously in the same person.

Precipitation of malarial paroxysms by surgical injuries.—Dormant malarial infection is frequently awakened by accidental traumatic injury or even by the surgeon's knife in ordinary operations. Injuries of the spleen appear to be specially connected with arousing slumbering malaria.

METHODS OF MEASURING THE ENDEMICITY OF MALARIA IN INDIA.

General remarks.

The accurate measurement of the endemicity of malaria in even a small district is an enormous undertaking. Let us see what such an estimate entails. It embraces amongst other points—(1) The malarial index; (2) the general parasite rate; (3) spleen index; (4) the variety of plasmodia met with in the blood of inhabitants and their relative proportions; (5) the sporozoite rate; (6) variations, seasonal and other, of local endemicity and the causes of these; (7) varieties of anophelines present, an investigation as to which are the natural malaria-carrying ones amongst these, and the proportion of malaria-bearing anophelines to those that are not natural carriers; (8) hiding places of adult anophelines; (9) localisation of all breeding places of anophelines; (10) areas of special prevalence; (11) general drainage of the country; (12) local meteorological and geological relations of malaria, and the manner in which these affect the breeding of anophelines; (13) local malarial statistics giving the malaria case-incidence of previous years and at the time under inquiry. Incidentally such points as the æstivation of adult anophelines, and the hibernation of adult or larval anophelines, and other questions such as the relation of relapses and re-infections, immigration and emigration, to the prevalence and perpetuation of the local malaria, might be inquired into.

An inquiry into the malaria of a district should last at least twelve months and should show the monthly variations of the factors engaged in maintaining endemic malaria. Under any circumstance the scientific and accurate investigation of malaria of a locality is an arduous and prolonged task. Take the question of the sporozoite rate. In a full inquiry hundreds of several varieties of anophelines may have to be dissected, and those who have done this know what a labour it is. Again the taking of the malarial index in the case, say, of 1.000 children, spread over 15 or 20 villages in an area of 25 or 30 miles, involves a considerable amount of labour that does not appear in the subsequently recorded facts.

With reference to the sporozoite rate, where anophelines are very numerous, it is possible to go through many hundreds of dissections without finding a single insect with either sporozoites in their salivary glands or zygotes in the stomach walls.

The finding out of all breeding places of anophelines, the species of ova and larvæ in these places, their collection, breeding out, and carrying on experimental malaria with them, all form part of a complete malaria inquiry and are associated with their own difficulties. Hence it is that malarial inquiries of a reliable kind in India are very few.

The malarial rate may vary in the same locality within wide limits during different years. Malaria is now only very mild in places where it was formerly severely prevalent, it has increased enormously in certain parts of India where it was previously comparatively trifling there are localities with sudden fluctuations, and there are others where it is permanently high or permanently low.

The endemicity even in the more pestilential malarial areas varies very much—it may range from being a pandemic with irregular periodicity, to that of an ordinary endemic locality. All the conditions in two places within a few miles of each other may be the same, yet the malarial index of one is very high, and in the other very low or even at zero.

Whilst malaria is universally distributed in this country, it is essentially a local disease; it is sometimes found to adhere to certain parts of inland towns and cantonments for years, extending beyond these only during epidemics and pandemics of malarial infection. In some cases it is at once possible to discover the essential causes of this localisation, in others the enquiry is exceedingly difficult, possibly because they are connected with epidemiological conditions regarding malaria that are still unknown.

It is necessary therefore to inquire carefully into the endemic indices over large areas to get an accurate estimate of the variations in endemic malaria in a district or province.

After ascertaining in a general way the chief facts concerning the province, district, town, cantonment or series of villages, we should make a close malarial survey of each district, and every part of the district, to enable us to explain the causes of the variations that will be met with.

The malaria rate of any place is not easy to calculate with any degree of accuracy, as there are so many factors which may disturb malarial statistics—accuracy of diagnosis, non-reported cases, cases not treated, cases of infection keeping at work, and so on.

In some places to acquire an accurate knowledge of the endemicity of malaria in the district is, from the conditions of life of the people, a task of the greatest difficulty.

In measuring the amount of malaria in a town, district, series of villages, or in a garrisoned cantonment, we should proceed systematically. One of the more important points on which information is to be accumulated is the previous history of malaria in the locality as ascertained by all locally available statistics, together with the general sickness rate and mortality.

Malaria statistics of a district, town, etc.—In estimating the malaria of a locality it is desirable to collect all recent statistics regarding malaria available. In a district we would inquire into the hospital statistics of malarial cases, including deaths from malaria. In exceptional cases where the diagnosis is completed such statistics may be most useful, but usually they are of very little value. The unreliability of most Indian statistics, except those published by the Sanitary Commission with the Government of India in Simla, is generally admitted.

Nevertheless the statistics acquirable in districts give us information that would take some time to gather without their aid ; they should not therefore be ignored. Whenever possible it is advisable to gather one's own statistics in malarial inquiries. Whenever this is done the manner of ascertaining the data should be defined and recorded, so that their real value can be estimated by others.

In the estimation of endemic malaria of a locality we should take into account only *fresh infections*. The large majority of cases occurring in late summer and autumn are fresh infections, whilst those occurring during the winter are relapses from infections that occurred during the preceding autumn or late summer months. The proportion of these relapses is largely governed by the number of earlier fresh infections ; in years of great endemicity (with a large number of fresh attacks) the relapses reach their maximum during the winter. The factor of low temperature in winter is of importance in relapses by reason of its causing chills.

Most of these points got by careful inquiry should be confirmed by the observer, or by other methods used to check them. Such information often gives useful guidance as to the direction of research in a district or town.

In estimating the value of statistical inquiries in malarial diseases, as in connection with other infective maladies, one should invariably keep in view the degree of probable error in each calculation. In this connection it is unnecessary to emphasise the importance of applying POISSON'S *formula* to all small groups of data. The formula itself of course only deals with the actual figures applied to it. It has nothing to do with the various sources of error liable to be met with in the figures themselves, such as errors in observations, defects in the actual units employed in the group of figures, etc. The wide degree of variation in future identical groups as shown by Poisson's formula indicates how essential it is to have a reliable number of observations to work on before arriving at positive opinions. With faulty observation the multiplication of figures can only magnify the error and lead more astray. With all their possible sources of error, however, statistics, when gathered from reliable sources, are our most trustworthy guides.

Control operations.—When estimating the value of anti-malarial measures we should not omit control operations of comparable communities as regards intensity of malarial endemicity—such operations being, of course, omitted in the "control" areas.

Possible errors to be eliminated.—All calculations, as regards the actual malarial intensity of a particular locality to be reliable, require the utmost care, and the elimination of possible errors. Such inquiries always mean hard work. Any one who has taken the endemic index of malaria in even a comparatively small district containing, say, 1,000 children, for a period of six consecutive months, tabulated in age-groups by the month for different villages, knows the considerable amount of labour involved, and that, usually, under somewhat trying circumstances, apart from the possible opposition of the people themselves.

Malarial map.—The *geographical and topographical distribution of malarial diseases* in the area should be noted, together with the varieties of parasites of malaria met with, and the localisation of adult malaria-breeding anophelines and the breeding places of their larvæ.

Maps drawn to definite scale should show the points required in distinctive figures, letters, or signs. Where the factors regarding which notes are to be made are present, they are marked with a plus (+) sign, and where absent with a minus (—) sign. Places not investigated should also be marked, otherwise they may be thought to be negative, and erroneous conclusions as to the distribution of malaria arrived at. All streams, wells, collections of water should be shown and all places where anophelines may breed. In ascertaining the incidence of malarial diseases in a town or village, or group of houses, a plan of these should be drawn and the houses or huts infected indicated in the way described above.

General and special malarial survey to be made before commencing an anti-malarial campaign.—Whenever an anti-malarial campaign is to be adopted, we should make a general and a special survey of the area to be operated on as regards the different sites of ponds, pools, and all collections of water in the place, ascertain the extent to which larvæ inhabit these, and the species of these larvæ. In doing this the use of a white vessel should not be omitted, as on the white background of such vessels in water, with a little experience, the kinds of larvæ present can usually be spotted. Such a survey in its entirety also includes an accurate record of the endemic index of malaria, the sporozoite rate and the spleen rate of the district, together with a critical examination of all hospital or other records as regards malarial fevers for the preceding ten years, if such records are available.

Endemic index of malaria.—STEPHENS and CHRISTOPHERS and KOCH have shown that the number of native children with malarial parasites in their blood is the best estimate of the malarial intensity of a place; and from this STEPHENS and CHRISTOPHERS evolved their now well-known *endemic index of malaria*, or the percentage of children with malarial parasites in the peripheral circulation. To be reliable, of course, the figures of malarial endemic indices should be large—with small numbers the probable error may be so great as to considerably lessen the intrinsic value of the figures.

Endemic malarial index of a locality.—Having decided on the locality to be investigated, a village, part of a town, *bustee* or series of *kinthals*, we get the assistance of the European (if any) and native officials, magistrates, sub-collectors, patwaris; in a cantonment of the Cantonment Magistrate, Station Staff Officer, and regimental authorities, etc. Have a muster of the children made. Do a spleen test first, as this gives no bother and will assist in taking the blood films subsequently. Take a few films of adults and older boys as a preliminary to taking those of the younger children. The little operation should be carried out with the least possible fuss. A single smear from each is usually sufficient. If the area is but slightly malarious two films may be made from each child. The more taken, the greater will be the accuracy of the test. One has practically never experienced any trouble in taking the malarial index of bazars or villages. A small feast of bazar confectionery at the end of the process, or a copper for each child, removes all difficulties.

Age-groups of children in endemic indices.—In taking an endemic index it is necessary to take age-groups, and the actual number of slide preparations of blood of each child should be recorded. In some places the endemic index may be 100 per cent. This was the case in Ennur, Madras, during STEPHENS and CHRISTOPHERS' observations. The same authorities found that in the villages of West Africa the blood of 90 per cent. of the babies contained malarial parasites, children up to 8 years 57 per cent., up to 12 years 28 per cent., and over 12 years they were rarely infected. At the village of Maram in Manipur, in the month of December 1904, when taking the malarial index of the place, one found that of 72 children between 0 and 10 years of age, 70 had malarial parasites in their blood. In most malarious districts it will be from 25 to 50 or 60 per cent. The endemic malarial index varies with the age of the child. It is highest between 1 and 2 years, decreases between 3 and 10, and is lowest after 12 years. When making comparisons of the malarial endemic incidence of localities, this age-incidence is a very essential factor, considering the probable disparity and rapid decrease in numbers of children affected by malarial parasites after ten years of age. It is therefore important that in comparing one district or village with another, the figures for comparison should be in age-groups. "By investigating the blood of children in this way remarkable variations in malarial endemicity are found, and it is the easiest and best way of getting a true idea of the intensity of malaria in any place. Further, the monthly variations in malarial intensity can be readily followed by this method, and we have in it a simple and satisfactory way of estimating whether anti-malarial measures have had any effect whatsoever"—(*Stephens and Christophers*).

An absolutely correct estimate of the amount of malaria in a locality would necessitate the examination of the blood of every person in the locality. This in any investigation is practically impossible.

It would also necessitate similar examination in the case of all persons coming to the place to ascertain that they did not import malaria; this examination of the residents would determine the number actually infected in the place. We would then have two groups—the *imported cases* and those that are indigenous, and "the ratio of the numbers of each class to the total population might be called the *infected malaria rate,* and the *indigenous malaria rate* respectively" (RONALD ROSS).

When we refer to the amount of malaria in a locality, both these classes (imported and indigenous) are included, since both are liable to relapses. The malaria in a place signifies the malaria acquired in it. It is not always easy to recognise the indigenous from the imported malaria. Cured cases of imported may be re-infected indigenously. Many indigenous cases leave the place. Still in most normal populations emigration about balances the immigration. In military cantonments however the number of imported malaria cases may be very great, and the same holds good for some hill stations. In some hill stations these are the only cases of malaria met with. Reports of complete investigations would embrace both the *monthly and annual infection rates* in a locality.

The number of cases of malaria in a place in a given time to a considerable extent depends on the number of infected anophelines; this latter depends on the number of anophelines that have bitten infected persons. The former could be calculated if we could estimate the latter. Ross states:—"In a village in which there are 1,250 people, 750 infected persons and 3,000 anophelines, the malaria rate is 0·6, the number of anophelines to each person is 24, the monthly infection rate per cent is 0·72. That is, if a person lives in the village for a month his chances of becoming infected will be as 72 to 10,000," and he works this out by an elaborate mathematical formula which need not be here further referred to.

When a place is very malarious at particular periods of the year the infection rate is very high at such periods. There may be comparatively little malaria at other seasons.

Once a high endemic index or spleen rate is established in a locality, a comparatively small malaria-bearing anopheline population is capable of maintaining a high endemicity. There are stations in which a small neglected stream, a few tanks or collections of water keep up the anophelines from year to year.

In the same way an area with a high degree of endemicity, so long as cases of malarial infection remain untreated, continues to be endemically malarial for some time after the breeding grounds of anophelines have been abolished, probably because a comparatively few anophelines immigrate to maintain the malaria, or possibly some unnoticed source of anophelines, such as a disused well, remains. This may be the explanation of the seeming failures of some anti-mosquito measures. This indicates the necessity of combining both anti-mosquito and anti-malarial measures—removing breeding grounds of anophelines and treating all cases of malaria with quinine for a period of three months.

Care of slides and records.—When there are a great number of slides for examination, each should be numbered and dated at one end, and the note-book carried should contain all the other particulars of the case, each case having, of course, the number corresponding with that of the slide. Grease or wax pencils are invaluable for quick work in marking slides, and a supply of these pencils should be at hand.

Sporozoite rate.—The *sporozoite rate* means the percentage of malaria-bearing anophelines found to have sporozoites in their salivary glands in the natural state. It is convenient to include in this anophelines with zygotes in the midgut; when this is done the fact of their inclusion and the number so included should be stated. This is a most laborious undertaking, but the results give very solid value when worked out. With a staff of trained assistants this labour may, of course, be greatly reduced, but when working alone, the task is a heavy one. Considering the great importance of the sporozoite rate as an initial step to public malarial prophylaxis, one is surprised to find so few instances in which the salivary glands of, say, several thousands of anophelines have been dissected out in malarious places, and the results of the finds recorded.

Romanowsky stain.—It may be stated that when making a malarial survey of a district as regards types of fever, one can work much more rapidly and reliably by working with good dried specimens stained in Romanowsky than in any other way. The Romanowsky stain is unrivalled for the demonstration and study of the structure of malarial parasites. For mere diagnostic work, which may be considered comparatively coarse as we are dealing with bodies which are bacteriologically fairly large sized and definite, any of the ordinary stains such as thionin, toluedin, eosin and methylene blue, etc., answer very well. The various modifications of Romanowsky—Leishman's, Giemsa's, Louis Jenner's, etc., also give satisfactory results, whether in tabloids or crystals. The modification of the Romanowsky stain in general use in India is LEISHMAN'S (see p. 91).

Regarding the stained blood smears we should ascertain the number of films showing parasites or pigmented leucocytes, and the percentage value of each species of the plasmodium, if there are a sufficient number to make this a useful record.

Where one has abundance of time and can carry out the examination at once, it is always preferable to make an examination of one fresh and one stained slide. When a large number of cases have to be investigated in a limited time, as usually happens in an inquiry into the malarial endemicity of a locality, stained slides are preferable for many reasons. Fresh films should be examined as soon as possible, but when "ringed" with vaseline they will keep many hours. Usually a few minutes' examination suffices for diagnostic purposes, although it may take half an hour to grasp all the peculiarities of some slides.

The specific points of the cases to be ascertained are used as headings and noted at once. When moving about in districts Leishman's stain is the handiest and, most readily carried out, and, when working under pressure of time, highly satisfactory.

Parasite rate.—The *parasite rate* is the proportion of persons of all ages harbouring malarial parasites in the blood. It is useful but necessarily limited to small numbers of people in a town or district. It is most useful in small communities or small bodies of men such as troops in garrisons, prisoners in jails. It is of course impracticable on a very large scale. Hence when an extensive inquiry is undertaken we are obliged to go by averages taken from a limited number of blood examinations.

Percentage value of leucocytes.—The chief characteristic change in the leucocytes in malarial infection is an increased percentage of large mononuclears, so that at times they may be equal to the polymorphonuclears. This is especially during the apyrexial period of malarial fevers, when there is a leucopœnia. "If from any cause a leucocytosis is present the increase of large mononuclears may not be evident." Anything above 15 per cent of mononuclears is valuable as an aid to diagnosis in the absence of parasites. When large mononuclears are characteristically present, they are to be found in every field and some of them may be pigmented. When scanty a careful differential count *over several slides* may be necessary.

Relative count of leucocytes is specially useful in cases where quinine has been taken, where diagnosis is uncertain, or where enteric fever or other infective fever is suspected.

Spleen index.—The *spleen index* one would define as the percentage of native children between 0 and 10 years of age with malarial enlargement of the spleen. It should not, in India at least, be limited to children between 2 and 10, as one has ascertained that 32 per cent. of children between 0 and 2 years suffer from enlargement of the spleen in endemic malarial districts. The *general spleen rate* is the percentage of the entire population with enlargement of the spleen. As previously stated a real and scientific estimate of the actual amount of malaria in a country would involve the blood examination of every person for parasites. This is of course impossible. The next best method of measuring existing malaria is the malarial index, that is, the percentage of children from 0 to 10 years of age harbouring parasites in their blood. When the

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figures are sufficiently large the probable error here is small. But even this is impossible. No investigation, however comprehensive, could undertake the examination of the blood of all children in a district. One would here advocate for *general* adoption the use of the *spleen census* instead of the endemic index and parasite rate, as a means of giving us a rough estimate of the amount of malaria. As far as rural malaria is concerned, the village headman is quite capable of diagnosing enlargement of the spleen, and he could be entrusted with keeping up for each year a register of the general spleen rate (the spleen enlargements in all ages of his village community) and that of children between 2 and 10 years.

It is conceivable that were sufficiently extensive observations on the general parasite rate, endemic malarial index, general spleen rate, spleen rate of children made, with the ratios existing between these in the same districts, we could eventually formulate from these the actual malarial rate from the spleen rate. These original observations would necessarily have to be accurate in every detail.

The spleen test is a valuable aid to an inquiry when the age and race are also recorded. In general terms it may be said that when cases do not run into malarial cachexia, the spleen does not continue to enlarge, once some degree of immunity is established. It is easy to carry out, and a large number of people can be examined in a short space of time. If we can exclude kala-azar in the locality under inquiry, the spleen index is most useful. In extensive inquiries which have to be carried out in a short space of time, it is the best test of local malaria we can obtain. Malarial spleno-megaly indicates previous not recent infection. It is, of course, not so reliable a test of previous infection as in finding Hæmosporidia, as hypertrophy of the spleen may arise from several other causes. DANIELS says :—" A large proportion of enlarged spleens between 2 and 5 years of age is an indication of a high endemic index" and is then often co-existent with current malarial infection in the spleen cases.

In their investigations on children with splenic enlargement and the presence of malarial parasites in their blood STEPHENS and CHRISTOPHERS found :—

(1) In the early ages, one and two years, the number infected is usually in excess of those showing splenic enlargement;

(2) Above two years the spleen rate is usually somewhat in excess of the parasite rate;

(3) Above 10 years the spleen rate is usually considerably in excess of the parasite rate."*

**Practical Study of Malaria*, 3rd Ed., p. 212.

In the blood examination of over 600 children recently carried out in malarial districts the above corresponds with what one found.

An enlarged spleen does not necessarily mean present malarial infection—it is usnally the result of an antecedent infection. It is not often that malarial parasites are found with a chronically enlarged spleen in the absence of re-infection. In 101 cases of enlarged spleens met with on the hills due to antecedent infection the endemic index was about 10 per cent.

Wherever it can be carried out one would recommend a combined investigation of the endemic index, spleen index, general spleen index and general parasite rate. Were these carried out in sufficiently large numbers in various districts and their relative percentages estimated, we would eventually be able to determine the actual malarial intensity of a locality from the percentage of cases of enlarged spleen alone, and enlargement of the spleen is a physical condition that can be diagnosed easily.

Age of individuals examined.—Certain *precautions are necessary in employing the general spleen rate* to indicate the endemicity of malaria. Enlargement of the spleen from malarial infection usually disappears when the patient is no longer under malarial infection. In many malarious places the adult population is but little affected with splenic enlargement. In localities where kala-azar, or other causes of splenomegaly exists, the spleen test has to be used with caution. In regions where endemic malaria is of mediun intensity, or even mild, and this embraces a large part of the malaria in India, spleen enlargement is met with in the adult population to a varying extent.

A periodical spleen census is comparatively readily carried out by medical subordinates and is most useful where the more correct and reliable method of blood examination is impracticable. The spleen rate determines the localities that are mostly affected, it gives us some guide as to the effects of anti-malarial measures, and it marks the people, especially children, who require quinine treatment.

Many maladies cause splenic enlargement, but in India we need only specially concern ourselves with kala-azar or the condition of splenomegaly in which *Leishmania-donovani* are found in the spleen, liver, or blood, or in all three of these situations. Hence in most endemic malarial places in India this infection would have to be excluded before accepting the spleen rate as an estimate of the amount of malaria in a locality.

One great defect of the general spleen test is that a fairly large number of cases of present malarial infection in adults do not show splenomegaly. "The conditions that lead to splenic enlargement after malarial infection vary and are not thoroughly understood"—(DANIELS).

Another advantage of the spleen index is that it is not affected by meteorological changes as is the case with blood examinations; a sudden lowering of the atmospheric temperature or a shower of rain may light up relapses in dormant malarial infections.

As above stated it is always necessary to make sure that kala-azar is not endemic in the district. The few cases of splenomegaly arising from leucocythemia, Banti's disease and other causes are so rare, that they may be neglected in estimating general statistics of the malaria of India. Even one form of Banti's disease has been considered to be one of the ultimate effects of prolonged malarial infection.*

The endemic index shows current infection. The spleen rate indicates the general result of malarial infection during the malarial season; enlargement of the spleen, when untreated, continues for the greater part of the year, and the spleen index may be taken at any time. During the non-malarious season, especially in the late summer and before the monsoons commence, the parasite rate in children in malarious places may be very low, but the spleen index, although at this time at its lowest, is in such places always fairly high. In cases of splenomegaly during the non-malarious season, the parasite rate is as a rule low, parasites being then usually only found during the actual relapses.

The great advantage of the spleen index over the endemic index is the fact that it takes only a few seconds to examine and learn the particulars of each case, whereas blood examination takes at least a few minutes, excluding the time occupied in staining which may be done by an assistant. In Dehra Dun, in the village of Garhi, one examined 264 children for spleen enlargement in 67 minutes, and during this time noted the presence or absence of fever, anæmia, whether spleens were last year's or not, age of child, existence or not of malarial cachexia, and often the exact group of huts in which the children lived. The method adopted was to have all the children arranged in a row. An assistant wrote in a note-book the heading as regards name of station, bazar or group of huts. Then the children as they passed along bared the upper part of the abdomen, one palpated and called out the age, whether there was enlargement or not. Suppose the child were six years old, had an enlarged soft spleen and anæmia, I called out "6—1 A," if the spleen was large, hard and resistant, I called out "6—1 × (cross)." In this way the youthful population of a large village can dealt with expeditiously.

In children the percentage cases of positive blood examinations is usually less than the spleen index; the average endemic index in 600 blood examinations was 40 per cent., the average spleen index in 3,884 children was 60 per cent. There is no kala-azar in the stations

* The subject of kala-azar is referred to on pp. 126-127.

in which observations on these 3,884 cases of splenomegaly were made, and in only one instance was the enlargement non-malarial. It is not included. It was in a healthy looking girl of 7 years; the cause of the enlargement was not diagnosed.

The parasite rate in 250 unselected cases of enlargement of the spleen during the malarious season on the plains was only 24 per cent; 203 of these cases had suffered from recurrent fever during the previous two or three months, and five had fever when the observations was made.

The spleen index rises about six weeks after the commencement of the rains; the endemic index at this time does so much more rapidly.

The proportion of malignant tertian parasites found in cases of enlarged spleen in children is considerably higher than that met with in adults suffering from malarial fever in the same localities; for example the benign tertian percentage for Native Troops was 88 and the malignant tertian 12, as compared with 65 and 35 respectively in all children up to 10 years of age. I am unable to explain the reason for this fact, although its solution is of some importance in the epidemiology of malaria.

In spleen cases of children there is a higher percentage of malignant infections shown (as indicated by "crescents" or "malignant tertian rings") than in non-spleen cases. Of 281 children with enlarged spleens malignant parasites were found in 19 or about 7 per cent., and benign tertian parasites in 13 or 4·6 per cent. In 240 children without enlargement of the spleen malignant tertian parasites were found in 18 or 7·5 per cent. and benign tertian in 80 or 33·3 per cent. Except when the child was actually suffering from a paroxysm the number of parasites in all cases in the individual blood films (with or without enlargement of the spleen) was small.

The parasite rate up to two years of age is comparatively high; it ranged from 22 to 68 per cent. in different plains stations. From three to five years of age it was 19 to 37 and from five to ten years of age 11 to 21.

In places where there is a constantly high endemic index the spleen rate is almost as true a test of the measure of malaria as the endemic index itself, except in instances where a previously healthy locality has suddenly become malarious, or one in which for some reason from being an endemic area it suddenly becomes an epidemic one.

To give the most reliable results it is necessary that the spleen index be limited to the same age as the endemic index, *viz.*, 0 to 10 years, and that there be a moderate degree of uniformity in numbers in the distribution of the age groups of children.

All cases of enlarged spleen that continue from one year to the next are maintained by relapses which may occur at all times of the year, or by re-infections during the next malarious season; usually both these conditions co-operate. Over 97 per cent. of malarial enlargements of the spleen in children would disappear spontaneously within a year (often within a few months) without such relapses or re-infections.

In the normal condition without re-infection, all moderate degrees of malarial enlargement of the spleen disappear spontaneously in children within a year, and this occurs in children who have lived in malarious places and suffered from such enlargement for several consecutive years. This conclusion was arrived at after the examination of 987 spleens of native children at various hill stations in the 7th (Meerut) Division. These children are usually on the hills for a year, seldom two. The average spleen index of children in the stations they came from was about 60 per cent. The average in the native children on hills was 10 per cent., that is, in 50 per cent. the enlargement of the spleen had disappeared spontaneously within the preceding 12 months.

There were throughout my inquiry only three exceptions to this, in two the spleen was three inches below the left costal arch and in the other only barely palpable. In all three the spleens were decidedly hard and probably fibrosed.

The important inference from this is that in plain stations enlargement of the spleen is maintained by re-infections or relapses, or both those combined, and that if these can be prevented the enlargement will disappear, and with its disappearance probably malarial parasites will vanish from the blood.

This enlargement in children shows that the infection is continuous and repeated from one year's end to the other.

One has no hesitation in expressing the view that the spleen index as shown in native children from 0 to 10 years is a reliable measurement of the amount of malaria in most places in India whether it be a group of huts, bazar, cantonments, or in a town, so long as the numbers are sufficient to exclude a high degree of probable error.

One has ascertained that where the spleen rate is very high, that is over 65 per cent., the percentage of cases of spleen enlargements, extent of the enlargements, and the number of cases of malarial cachexia met with in children, bear a close relationship to the proximity of breeding places of anophelines.

The spleen index of European children cannot be taken as a measure of the malaria of cantonments. European soldiers' children have in many cases been to the hills for part of the summer or autumn, or both, and a large number have had quinine whenever paroxysms of malarial fever occurred. European children are better fed, housed, and cared for generally. Nevertheless the amount of malaria in European soldiers' children is an important factor in the malaria of cantonments. In a recent investigation one found that over 32 per cent. of these children had enlarged spleens, notwithstanding that over 35 per cent. of these children had been in the hills during part of the summer.

The spleen index attains its maximum value as an index of malaria in the children of native villages who get quinine neither curatively nor prophylactically, and notwithstanding the existence of medical officers, hospitals and quinine at their disposal, this is, with few exceptions, the condition that obtains amongst the children of our Native troops and followers, and the children of followers attached to Regiments of European Troops.

The degree of statistical error when a large number of children has been examined for enlargement of the spleen is not great. To indicate the limit of this error Professor RONALD ROSS employs a modification of Poisson's formula. "Let N be the total number of children in a locality, n the number examined, and x the number with enlarged spleens. Then $\frac{x}{n} \times 100$ will be the spleen rate among the n children examined. But we shall have no right to infer that the same rate will hold good for all the N children in the locality. Let e per cent. denote the percentage of error. Then e per cent $= \frac{200}{n} \sqrt{\frac{2x(n-x)}{n}} \sqrt{1 - \frac{n-1}{N-1}}$. Thus when $n = N$, or all the children in the locality are examined, the statistical error vanishes.

For example, let $N = 800$, $n = 200$, and $x = 100$.

Then $1 - \frac{n-1}{N-1} =$ about $\frac{3}{4}$, and $\frac{2x(n-x)}{n} = 100$. Hence e per cent. $= 5\sqrt{3} = 8{\cdot}65$ so that we can infer that the spleen rate of the total 800 children is between $50 + 8{\cdot}65$, and $50 - 8{\cdot}65$ per cent.; that is, between 58·65 per cent. and 45·35 per cent."

The employment of the general spleen rate as an index of the endemicity of malaria is not new in India ; and long before Laveran's discovery it was used by various committees for this purpose. The first occasion on record in India was that of Colonel Baker's Committee in 1845.

In September 1845, the Government appointed a Committee, with Colonel Baker, R.E., as President, and Surgeon-Major Dempster and Lieutenant Yule, R.E., as members, to report on the causes of the unhealthiness which existed at Kurnaul and other portions of the country along the line of the Western Jumna Canal, and whether any injurious effect would be likely to be produced on the health of the people of the Doab by the then contemplated Ganges Canal. In 1847 the Committee submitted their report. The endeavour of the Committee was to ascertain what relation existed between certain physical conditions of different districts and the liability of the inhabitants to malarial fevers. At the beginning of their inquiries they experienced much difficulty in obtaining reliable testimony on the latter point. In this difficulty Dr. Dempster suggested that the condition of the spleen in any number of individuals would be a fair test of the probable frequency and degree to which they had suffered from malaria, and this test the Committee adopted, and thus was established the test, which was long known as "Dempster's test," and it has been used in many subsequent inquiries of a nature similar to that which engaged Colonel Baker's Committee.* Dr. Dempster wrote :—" I have no wish to exaggerate the value of the spleen test. There may be different types of malaria, giving rise to forms of different types and having different complications and consequences, but from what I have lately witnessed, I am fully persuaded that it will be found a true and faithful comparative measure of marsh malaria in its extended sense, and with that canals and canal irrigation have any proper connection."

I have dealt with the subject of the *Spleen Index* and *Spleen Rate* at some length, as one is firmly of opinion that one or other of these is the only practicable method of gauging the malaria of India on a large scale, and also because one is convinced that it fairly accurately indicates the malarial intensity of a locality.

Species of anophelines present.—Species of anophelines found and those most prevalent in the village, town, cantonment or district are to be determined. As a guide to this determination JAMES and LISTON'S *Anopheles of India* and STEPHENS and CHRISTOPHERS' *Practical Study of Malaria*, 3rd Edition, are reliable guides. Wheu any species not there illustrated or described is discovered, and not identified, it should be carefully collected and mounted in the manner stated on p. 81.

Search for adult anophelines in huts, houses, out-houses, stables, etc., noting the species, their numbers, whether in swarms or abundant, or few and the relative number of each species. Estimate the numbers caught in a given time each day, say in a few hours, and with the same worker if the numbers are fairly large, in a week a fair estimate and average relative numbers should be available.

Some species are more frequently found in houses than others; the same anopheline may be more prevalent in some houses than it is in others.

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* F. N. MACNAMARA, *Climate and Medical Topography of British India*, p. 371.

The larvæ of the species found should be bred out, and it should be ascertained if they can become infected with human malarial parasites. This should be done with the imagines of the species bred from eggs if possible.

Infected anophelines present.—In carrying out an inquiry as to the prevalence of malarial infection in anophelines, it is necessary to catch a considerable number of adult anophelines from the village or quarter in, and adjacent to, where the spleen index or spleen census, and endemic index or parasite rate, were determined. We should dissect as many anophelines as possible, noting the species dissected, and in which species sporozoites are found, if in any. In these dissections the salivary glands of anophelines found should be examined for sporozoites, and the stomach for zygotes and sporoblasts. "In many cases the sporozoite rate is exceedingly low, *e.g.*, 2 per cent., although anophelines are abundant and the malaria index is not low. In others the percentage may reach 50." Specimens of each species should be kept alive for several days and then dissected to see if their stomach walls (midguts) contain oocysts of plasmodia.

Different species vary with the readiness they become malaria-carriers, and for reasons not yet determined, the same species varies in this respect under different circumstances. As a rule anophelines bred from larvæ are not as readily infected as adults caught in nature, but in the case of adults caught, it is possible they may have been previously infected. The conditions known to influence infectivity are the atmospheric temperature, age of the anopheline, whether she has been impregnated or not, food already consumed, and other undetermined factors. These latter require thorough investigation, and this can only be carried out in malarial areas.

Number of anophelines present.—The number of anophelines present in endemic malarial areas varies very considerably. There are some endemic malarial places in which the endemic malarial index is from 60 to 70 per cent., in which it is so difficult to find malaria-bearing anophelines that even expert malariologists may not succeed in capturing more than a few adults in an hour, and in which it is extremely difficult to find breeding grounds of larvæ. The Duars is said to be one of such places. "There are other places where malaria-carrying anophelines are so common that 20 or 30 specimens can easily be caught in an hour, but where the endemic index is not more than 12 or 15."*

It should be remembered that the coincidence of a marked decrease in the number of anophelines without decrease in the incidence of malarial fevers, can be readily explained when the immigration of previously infected persons continues, or when by any means the source of infection is increased. "The prevalence of the source of infection is a

* Major S. P. JAMES, I.M.S., *Malarial Fevers*, 3rd Ed., p. 48.

factor of equal and sometimes perhaps of greater importance than the prevalence of anophelines"—(S. P. JAMES). There are few statements in the whole literature of malarial epidemiology more comprehensive and more lost sight of than this. It gives an explanation to a vast amount of the malaria met with throughout India.

In endemic malarial localities the constant immigration of susceptible persons is one of the main sources whereby the disease is kept up. When such importation of susceptible persons is maintained in an endemic malarial area, every one becomes infected in a short time, even when the number of anophelines is very small, assuming that there are at least some malaria-bearing anophelines present.*

Where there are crowds of malaria-carrying anophelines, there are potentialities for the dissemination of malarial infection, even when those present are found by dissection to be free from sporozoites, zygotes, and sporoblasts. All that such a place to be rendered highly malarious requires is the introduction of susceptible people and cases of malarial infection.

The explanation of the large and rapid increase of malarial cases in groups of men working on railway embankments, irrigation and other canals, road-making, etc., is that anophelines are already present, cases of malarial infection are almost certain amongst the workmen, and through the anophelines, infection is rapidly spread. The new excavations created as work progresses rapidly multiply the number of anophelines, and so the diffusion of malarial fevers occurs with almost geometrical progression. In this way areas which were not known to be only slightly malarious have been converted into virulent malarious centres.

Groups of workmen unprotected by mosquito nets or otherwise, often three parts naked, are crowded into huts giving free access to anophelines. Amongst the work people are those carrying malarial sexual forms ready for anophelines, and other work people susceptible to malaria. A few persons who, it may be, have recently recovered from sub-tertian fever and have no symptoms, will harbour crescents and infect all anophelines biting them, and each of these anophelines is capable of infecting at least a few persons in the hut or adjoining huts. Conditions comparable with this exist throughout the rice-growing districts of India, Assam and Burma.

It is wrong in principle to assume that the predominating anophelines in a place, or the ones most easily captured, are the carriers of malaria in a locality; it sometimes happens that these are not malaria-carriers at all. This will frequently be found to be the case with *Ps. rossi* during investigations.

* CHRISTOPHERS and BENTLEY, *The Human Factor in Malaria*, read at the Bombay Medical Congress, February 1909.

It is probable that even in a malarious locality only about 25 per cent. of the anophelines are likely to succeed in biting human beings; only one-third of these 25 per cent. are likely to survive for a week or more, and only one-fourth of the remainder are likely to succeed in biting a second person. Hence only 1 in 48 is ever likely to give infection. (Ross.) No methods as yet devised can give us even approximately the average number of anophelines in a place.

Roughly in India not many more than two or three anophelines are caught in each inhabited room. One has at times futilely spent hours in searching for a single anopheline, where there were many malarial cases. Those found are often those who have fed on blood and are loaded with eggs. Most get away in the morning. When huts or houses are close to marshes, tanks or breeding pools, there may be a few hundreds to each inhabitant. In highly malarious places a large percentage of the adult anophelines captured near breeding places are infected The circumstances under which such captures are effected are very exceptional, and cannot be relied on for routine work as sources of infected anophelines.

We should obtain or prepare a map of the district, town, cantonment, or village, on a large scale, and on it locate all collections of water within half a mile from the nearest houses. We should also ascertain where anophelines are breeding, taking labelled bottles or test tubes for each collection of water, obtaining ova and larvæ from them, marking each bottle with a letter or figure having a corresponding mark on the located position of the collection of water on the map. We may attempt to identify a few larvæ and ova of each species, provided they are plentiful, but in all cases we should leave enough to allow adults to breed out and mark on the map the different species, and, if possible, the relative numbers of these. The distances of pools from houses should be accurately shown.

It is well to systematise each day's work, *e.g.*, using the mornings in capturing winged anophelines, the afternoons in identifying and dissecting them to ascertain if they have zygotes in the stomach wall or sporozoites in the salivaryglands. This is the most laborious part of a malarial inquiry and the part that occupies the most time.

Investigation of European malaria.—As in the cases of town and village inquiries, a map should be made of the houses or barracks occupied by the persons under investigation, the breeding places of anophelines within half a mile marked down, and the positions of all native quarters entered, the map, of course, being drawn to scale and the distances entered.

The blood of as large a number of Europeans as possible in the locality should be examined, the temperatures taken, ascertaining also by specific inquiry in each case whether quinine is being taken. We note the number having parasites, crescents or spherical gametes ; where no parasites are found the presence or absence of a relative increase of large mononuclears or of pigmented leucocytes should be noted. In all cases it is desirable to make differential counts of leucocytes. These points can all be ascertained from the one stained slide of each case. Note whether any section of the Europeans, or those occupying particular quarters, have a larger percentage of malarial infection. We record the condition under which they are living—near native quarters, breeding grounds of anophelines, condition of houses as regards protection by wire-gauze doors and windows, use of mosquito-nets, electric fans or punkahs, etc. We should specially note those groups of Europeans taking quinine regularly or otherwise. Any relation between the European malaria and nearness to native huts should be recorded.

As above stated the map should show the European houses and the position of all native huts near them. We enquire specially into the state of malaria in these huts by blood examination, presence of adult anophelines, and breeding grounds. This latter part of inquiry should embrace the percentage of infected children in each group of huts, degree of malarial infection in adults, number of anophelines present—roughly, abundant, scarce, or cannot be found, and in the last-named case, test pools should be made.

Ascertain the species of anophelines present, and their relative numbers; the sporozoite rate for each species; map of all breeding places, noting what kinds of larvæ are found in each. "Capture as many anophelines as possible in European houses or barracks, especially in the early morning ; look in mosquito nets ; determine their species, sporozoite rate, and whence derived."*

Investigations into the malaria of a locality to be accurate and reliable should be continued in the place throughout the entire year beginning, say, in August or September. During the year we make a record of *seasonal variations* in the endemic index (children under 10 years) ; seasonal alterations in number of anophelines present at all times during the year ; distance of flight of anophelines from their breeding grounds ; sporozoite rate in anophelines at different periods of the year.

There are places where malaria-carrying anophelines exist in large numbers without severe malaria occurring side by side with other places where both severe malaria and anophelines exist. This has been definitely shown in the work carried out by experts in this country, and without entering into the details of the special instances in which it has been met with, it is here stated as a fact which still remains unexplained.

* Stephens and Christophers, *Practical Study of Malaria*. 3rd Ed., p. 215 .

Having made a series of observations regarding malarial fevers located in special malarial centres, the particular breeding pools of malaria-carrying anophelines, and ascertained the huts or houses they favour, it might be thought that we should be in a position to explain scentifically and satisfactorily why malaria prevails in some places and not in others. We are obliged to confess that this is by no means always the case. There is still much about the habits of mosquitoes and regarding the epidemiology of malaria we do not understand.

Whilst the subject of anophelines is of vast importance in the study of malaria, it will be seen that there are other important factors which determine the prevalence of malaria in a locality, and it is necessary that we should be able to give the exact relative values of these factors in an investigation. Unfortunately our limited knowledge of these factors at present does not permit of the estimation of these relative values.

A diary of the work carried out should be kept up, and nothing should interfere with its being written up every evening. The more detailed it is, the more useful will it be when finally preparing the reports on the malaria of the places investigated.

PART III.—METHODS OF PROPHYLAXIS OF MALARIA IN INDIA.

Principles of general prophylaxis of malaria.—The principles underlying the general prophylaxis of malaria are—

1. That malaria fevers are due to a species of protozoon which invades the blood of man.

2. That this protozoon reaches the blood of man through some species of mosquitoes of the sub-family *Anophelina.*

3. That in these mosquitoes the malarial parasite carries out the sexual part of its life-history, undergoes developmental changes which are usually complete in from 6 to 10 days, at the end of which time they reach the salivary glands of the mosquito, whence they are discharged once more into the blood of man.

4. These malaria-carrying mosquitoes breed chiefly in terrestrial waters in tropical and sub-tropical regions. (RONALD ROSS.)

About the foregoing statements there is now not the smallest shadow of doubt. They are scientifically established *data.* In the preceding pages are to be found an overwhelming mass of evidence which bears them out.

In the present state of our knowledge it is reasonable to make three propositions :—

1. Were all mosquitoes exterminated, malaria would cease;
2. Were all persons protected against the bites of mosquitoes, no malarial infection could arise;
3. Were all existing cases of malarial infection cured, then malarial disease would be exterminated.

It is just possible that there is a gap in our knowledge, but for the practical anti-malarial sanitarian such a possible hiatus has to be ignored.

As corollaries to these three propositions we have the following :—

(1) If mosquitoes can be diminished or prevented from attacking man, the chances of dissemination of malaria are reduced.

(2) If cases of malarial infection are lessened in number, the chances of communicating the disease from man to man by anophelines are reduced.

Table of methods of prophylaxis.—The present day methods of prophylaxis of malaria are based on a consideration of the points already dealt with, and may be conveniently included under the following headings:—

A. Quinine in Malaria.

(*a*) The eradication of malaria from the entire population by quinine.

(*b*) Quinine prophylaxis.

B. Segregation of the healthy.

C. Isolation of infected persons.

D. Protection against adult mosquitoes by—

(*a*) Mosquito-proof houses.

(*b*) Personal protection by—

(*i*) Mosquito nets.

(*ii*) Punkahs and electric fans.

(*iii*) Mosquito-proof clothes.

(*iv*) Culicides.

(*v*) Culicifages.

E. Destruction of larvæ and removal of breeding places of larvæ.

Drainage;—

Regulation of surface waters.

Cultivation and arboriculture as anti-mosquito measures.

Removal of breeding grounds of mosquitoes.

Larvicides.

F. Prophylaxis in towns.

G. Do. villages.

H. Do. schools.

I. Do. military cantonments.

J. Anti-malarial measures in jails and asylums.

K. Anti-malarial measures for gangs of labourers.

L. Prophylaxis in houses.

M. Do. the individual.

N. Anti-malarial Legislation.

O. Education of the public in anti-malarial measures.

Causes and prevention of malaria.

P. Application of the principles of mosquito reduction to districts, towns, and military cantonments.

Q. Organisation of the workmen of mosquito brigades in gangs.

R. Expenditure on, and limitations of, anti-malarial measures.

A.—Quinine in Malaria.

A brief account of the introduction of cinchona bark into European therapeutics is given in the *history of malaria* (pp. 1—3). The alkaloid *quinina** was first extracted from the Peruvian bark by Caventou and Pelletier in 1820, and it was first used in this country about the year 1845.

Quinine should be up to the standard laid down in the *British Pharmacopœia*.—It is important that the salts of quinine, whether used curatively or prophylactically in malaria, should be up to the standard laid down in the *British Pharmacopœia* in the alkaloid *quinina*, and not lose more weight on evaporation at 212° F. than is allowed in that book. Sulphate of quinine should contain 73·5 per cent. or quinina, and not lose more than 12·5 per cent. of weight on heating to 212° F.

Quinine, the universally accepted specific against malaria.—Quinine is the universally accepted curative and prophylactic drug against malarial fevers; and it is for these purposes the nearest approach to a specific that we possess. It has a decided and distinct influence on malaria by killing the germs of the disease already in the blood.

In modern times a large number of substitntes for quinine have been introduced, some of which have been administered empirically, others because it is considered that from their effect on other parasitic forms, they should bring about the destruction of malarial parasites. In no single case can these substitutes compare in efficacy with quinine. These substitutes will not therefore be further referred to.

Method of administration.—Quinine is given by the mouth in solution, powder, tabloids or tablets, and pills. The majority of medical men in India consider that the most satisfactory way of giving quinine to produce the maximum effect in the shortest time, is in the solution by the mouth. Quinine in solution has the advantage of being quickly absorbed and producing its effects more rapidly than in any other way except by intravenous injection, which is only resorted to in pernicious attacks or persistent malarial infection resisting other methods of administration. Until recently throughout the Indian Army and in jails, this was the manner in which it was used both prophylactically and curatively. The use of tablets of quinine has now largely taken the place of the mixture. The ordinary quinine mixture consists of five

*The word *quinine*, unless otherwise specified, refers to the *bisulphate* salt of that alkaloid.

grains of the bisulphate (dissolved in dilute sulphuric acid) to an ounce of water. When 10 or 15 grains are to be given, 2 or 3 ounce doses of this mixture are administered—this is preferable to giving the larger doses in an ounce of water.

Many medical men in India now prefer the *hydrochloride or the bihydrochloride of quinine* to the sulphate. The bihydrochloride contains 81 per cent of the alkaloid, while the sulphate only contains 73·5 per cent; it is also said to be more stable, and to reach the blood more rapidly. In whatever form quinine is used, it is better to adhere to a uniform method of administration, both curatively and prophylactically. Quinine is given in the form of powder by the mouth with the object of escaping the bitterness of the mixture. Ordinarily in powder the sulphate is taken in wafer paper or suspended in milk, or washed down with some water, tea, etc. In this form it is inferior to the solution by about 20 per cent., hence a larger dose has to be given to produce a corresponding effect. It is suited to those who have great repugnance to the bitterness of the solution.

Euquinine.—This is the ethyl carbonate of quinine and is now being used to a small extent instead of quinine; it is taken in the form of powder; if dissolved the bitterness of the quinine returns. As it is weaker in the alkaloid quinine, it has to be given in doses 1½ times as large as the bisulphate. Euquinine is just as efficient as quinine in malarial fever, and causes malarial parasites to disappear from the blood in the same way. Its tastelessness renders it useful in children. Much has been written about the possibility of euquinine displacing quinine in the treatment and prevention of malaria. As far as this is concerned on a large scale in India, this is only a very remote possibility. The drug is eight times more expensive than quinine, and the quantity imported and the demands for it are comparatively small.

The bitter taste and occasional irritant action of quinine solution on the stomach has led to the use of the drug in pills, and tabloids or tablets. It is necessary to state however that these are never so reliable as the solution, chiefly because of their partial insolubility in the digestive juices. Tablets or tabloids are better than pills, unless the latter are quite fresh.

In practically all cases full cinchonisation by quinine is followed by ringing in the ears with some deafness, and in a few cases slight giddiness. Actual dangerous symptoms of quinine poisoning are rarely met with. One has on only four occasions met with alarming symptoms from large doses. All four had taken from 35 to 52 grains in 24 hours. The general effects were—trembling, pallor, agitation, restlessness, anxiety, profuse sweating, palpitation, weak and frequent pulse; in one there was temporary collapse.

Intravenous and intramuscular injections of quinine.—Injections of quinine, whether intramuscular, intravenous or hypodermic, must always be carried out with the strictest possible antiseptic precautions. The skin should be washed with soap and water, alcohol, and subsequently with corrosive sublimate solution. It is preferable to use an all-glass syringe, with a gold or platinum needle. Before use the syringe should be thoroughly boiled and the needle heated to a red heat.

The solution itself should be sterilized by boiling, and when practicable, made up fresh each time it is used. In hospitals where several such injections may have to be given to patients, a stock solution may be kept on hand, or preferably single doses kept in small sealed glass tubes, 7½ grains in each dose.

For a stock solution one would recommend —

Bihydrochloride of quinine—75 grains.
Sterilised distilled water—150 minims.
Fifteen minims of this contains 7½ grains.

These injections, and those of the bihydrobromate, are almost painless. Children tolerate the intramuscular injection of quinine quite as well as adults; one has no personal experience of intravenous injections of quinine in children.

Some difference of opinion exists as to the utility of this method of employing quinine. One has met medical officers who use it in almost every case, even in the more innocent forms of malarial infection and that with marked success, whilst many never use quinine in this way. Personally one considers that the intramuscular injection of quinine should be reserved for severe cases of malignant tertian, pernicious attacks, really intractable cases of the more innocent forms of malaria, and persistent relapses.

In this country where tetanus bacilli occur in the dust of every room, on every floor, and in the surface earth almost everywhere, the possibility of an accidental infection through either the solution or the hypodermic syringe, is a fact to be kept constantly in mind.

The quickest cinchonisation of the blood is effected by intravenous injection, and when a decided effect is imperatively necessary for the safety of the patient in an overwhelming malarial infection, this is the best method of administering in.

Quinine should never be used hypodermically.

Dosag.—When administered *for the cure* of malarial infection, children under 1 year may get from ¾ to 1½ grains twice a day; those from 1 to 5years. 1 to 3 grains twice a day; 5 to 10 years, 5 grains twice a day; 10 to 15 years, 10 grains twice a day; after 15 years. adult dose; adult dose, 5 to 20 grains twice a day. In heavy infections theatening to overwhelm the system. 50 per cent. more than the quantities nam d may be given. *Prophylactically*, the dose is the same, a dministeed in one of the several ways detailed on pp. 163, 164.

Action of quinine on malarial parasites.—Quinine destroys the parasites in the circulation The other physiological effects of the drug on the human economy are quite insignificant in malarial fevers compared with this main action. That it has little if any effect on the circulating white corpuscles is shown by the fact that large mononuclear cells are found at certain stages of malarial fever containing melanin, and they may be seen on fresh slide preparations in the act of engulfing melanin in cases that are taking full doses of quinine.

It is stated by most authorities that quinine has no toxic effect on spherical gametes and crescents. This, one takes the liberty of stating, is not quite correct. Quinine leads to a rapid reduction of spherical gametes of both benign tertian and quartan, but to a slower diminution of crescents, especially of crescents after relapses of malignant tertian fever. One emphasises this, as it appears to be largely a traditional statement in medical literature that quinine has no effect on gametes.

One has made an extended series of observations on the effects of quinine on malarial parasites, including gametes, and in connection with the latter one will only refer to a few cases to show that quinine has a decidedly toxic effect on them. On the 8th July 1909, a Garhwali, *æt.* 22 years, anæmic, with a spleen two inches below the left costal arch, came under observation for the first time at 10-30 A.M. He had been having fever for 12 days; the blood was examined and found to contain enormous numbers of benign tertian parasites. In ten minutes' time swarms of microgametes were flagellating; in one field ($\frac{1}{16}$ Obj., No. 4 eyepiece) 9 were counted, and in 25 minutes swarms of free flagellæ were moving about on the slide. The percentage of red cells infected was 5·5, of which (approximately) 2·5 were gametes. There were 27 per cent. of large mononuclear cells, of which 3 per cent. contained melanin. One ten grain dose of quinine was given at once and repeated at 4 P.M., a third ten grain dose was given at 9 A.M. on the 9th, when the blood was again examined, the temperature being normal. Not a single parasite could be found in seven stained slides examined, nor in four thick film preparations; the only discernible indication of malarial infection was a continued large mononuclear increase, none of these cells now containing pigment. The blood was examined every 12 hours subsequently for five days with negative results.

On the 26th June 1909 two Gurkha lads, brothers, aged about 17 and 18 years, were admitted with malignant tertian fever. In both every field of the examined blood contained malignant tertian "rings," the percentage of infected red cells in one was 2·8 and in the other 2·4. In all these cases a count of 1,000 red cells was made. In the former one counted 25 crescents on an average in four slides, and in the latter 11. In the younger boy the spleen was considerably enlarged and he was pale. Each got 30 grains of quinine in solution on the 26th. On the morning of the 28th there were no "rings," and it was difficult to find any crescents in the blood of the elder boy and only two to the slide in the younger. Five slides in each were examined.

On the 29th September 1906 a Gurkha, *æt.* 25 years, returned from Assam (where he went on furlough) with an enlarged spleen, anæmia, and regular paroxysms of quartan fever. The blood contained numerous quartan parasites (0·4 per cent. of the red cells were infected) and about 8 spherical gametes were found on every slide. Thirty grains of quinine were given on the 29th. On the 30th examination of 7 stained smears of blood was quite negative, and continued to be so for twelve days after which the man left the hospital to attend daily for quinine.

In the blood "the spores are the most sensitive (to the action of quinine); then come the large organisms that have completely replaced the blood corpuscles, and finally the endoglobular young forms, for which the blood corpuscle acts as a protecting mantle. Golgi found the endoglobular young forms of the tertian parasite very sensitive, and he produces that the hypertrophy of the blood corpuscle produces a relaxation of the structure which permits the quinine to pass through it." (Mannaberg.)

Quinine causes a degeneration of the parasite which is especially marked in the younger form and is most marked at the time of segmentation.

Quinine acts upon the malarial parasite in that phase of the life-cycle in which they are nourished and developed. When the nutritive activities cease by an arrest of the transformation of hæmoglobin into melanin, and the reproductive phase begins, quinine is inefficient in its action. Quinine is specially active from the time of segmentation until pigmentation commences within the red cell.

It will be found that under the action of quinine there is a loss of amœboid activity in the parasites in the blood, and a granular degeneration of the intracorpuscular forms; the intensity of the staining is lessened and this is specially the case with regard to the chromatin which does not occur in blocks or clumps, but as small dots or granules irregularly scattered, the blue margins of the parasites are more defined, and are seen as little lumps or knots at the circumference of the parasite, while the pigment occurs as fine dots. "The red cell containing the parasite may appear to shrink as well as the parasite within it." A special effect of quinine observable in stained preparations of the ring forms of all malarial parasites is that the white vesicular part of the nucleolus stains blue.

Such changes are best seen in simple tertian and quartan under quinine, but they are also seen in malignant tertian. "In malignant tertian the young amœboid forms appear greatly shrunken, their protoplasm more or less granular, and amœboid motion is lost." One has personally followed these changes in the parasite under the influence of quinine by hourly examination of the blood in stained and fresh preparations. They may be followed by any observer in every case of simple tertian of any severity where quinine is given comparatively early after the beginning of the attack.

The amœbulæ thrown into the blood plasma during sporulation are highly susceptible to the lethal effects of quinine, the intracorpuscular forms much less so. A single large dose of quinine, given just before a paroxysm of either simple tertian or quartan is expected, will destroy most of the young brood, without modifying the succeeding attack of fever. The probability is that if it has been given at the right time in sufficient quantity, there will be no new paroxysm, or only a very modified one of much less intensity. Nevertheless it is strongly recommended that the patient should continue the drug for at least three months even if he migrates to a non-malarial place, and that if he continues in the malarial place during the malarious season, he should take it for four months.

The object of giving quinine is to kill the parasites; to effect this it has to be in a certain degree of concentration in the blood. No matter how administered the greatest part of the dose of quinine does not reach the blood for a few hours after its administration; and as its slow excretion from the blood begins at the same time that it reaches that fluid, when decided effects are required (as in pernicious attacks) the fullest possible doses are to be given. These remarks emphasise the uselessness of small doses when a pronounced effect is demanded, unless these are repeated sufficiently often. Investigations have shown that when quinine bihydrochloride is given in solution by the mouth, its excretion commences in from ten to fifteen minutes. The excretion reaches its highest point in about 12 hours, after which up to 48 hours, traces of it only are found in the urine. In the case of sulphate of quinine solution the excretion begins in 45 minutes and is completed in 60 hours.

The malignant tertian parasite is somewhat more resistant to the action of quinine, and the intracorpuscular forms are not effected to the same extent as in benign tertian and quartan. The principle of quinine treatment in malignant tertian is to pour as much of the drug into the system as practicable without injury to the patient. If anything interferes with giving the drug in the ordinary way we introduce a solution of the bihydrochloride intramuscularly or intravenously. From 5 to 10 grains are dissolved in 20 minims of warm sterilized water and injected every six hours until a decided impression is made on the pyrexial phenomena. In the more severe cases the larger dose may be repeated for two occasions at four hours' interval. In using the drug in this way it is necessary to observe the strictest antiseptic precautions as regards the skin, instrument employed, and the solution. The needle is put to its whole depth into the gluteal region or deltoid muscle.

Under no circumstance is it necessary to give more than 35 grains intramuscularly, or 45 grains by the mouth, in the day.

If given by the rectum then two 25-grain doses of the bihydrochloride may be given.

In malignant tertian fever of mild type the time of administering quinine may be determined by blood examination. The occurrence of a large number of parasites in association with concentrated pigment indicates that a paroxysm is about to occur. The drug should be given at this time.

If quinine is to do good it most frequently does so in a few days. To keep pouring into the system 30 grains a day for weeks when it is doing no good is decidedly wrong. Yet this is frequently done. It should never be given for more than 5 days unless we know definitely that it is malarial infection and malarial parasites are still found in the blood. Cases in which quinine is given in large doses without effect on the fever are probably not malarial, or if so, are malaria with enteric, or with some complication, or it may be some other lasting fever possibly of septic origin.

One has undoubtedly seen quinine pushed too far in some cases of malarial infection. It should be remembered that quinine when administered to excess may injure the nervous system and reduce the power of endurance; and it is said that it may itself lead to some alteration in the red cells of the blood.

Quinine acts more promptly in malarial fevers when the bowels are well opened, and as in these fevers there is a tendency to constipation, it is well to commence quinine treatment with a purge such as a dose of calomel and compound jalap powder, or magnesia sulphas, or a Seidlitz powder.

The following is the general plan one would advocate for a three months' course of curative quinine treatment. The method begins after the last paroxysm or series of paroxysms.

First week.—

(*a*) In *double malignant tertian* (quotidian), 30 grains daily for 3 days, and then 20 grains daily for another 3 days, none on the seventh day, making 150 grains during the first week.

(*b*) For *ordinary malignant tertian*, 30 grains on the day of the next expected attack, and continued on alternate days until 120 grains have been taken during the first week.

(*c*) For *double benign tertian*, 30 grains daily for 3 days, and then 20 grains daily for 3 days, none on the seventh day, making 150 grains in the first week.

(*d*) For *ordinary benign tertian*, 30 grains on the day of the next expected attack and continued on alternate days until 120 grains have been taken during the first week.

(*c*) For *ordinary quartan*, 30 grains on the day of the next expected attack and continued every third day until 120 grains have been taken.

For double and triple quartan the intervals between the doses would be shorter, and the amount of quinine to be administered in the first stage of the course larger.

From the end of the first week the course may be the same for all types of malarial infection.

Second week.—15 grains daily.

Third and *fourth weeks.*—10 grains daily with 20 grains every seventh day instead of 10.

Fifth to *eighth weeks* (inclusive).—10 grains daily.

Ninth and *tenth weeks.*—5 grains daily with 10 grains on two consecutive days each week instead of 5.

Eleventh and *twelfth weeks.*—5 grains daily with 10 grains instead of 5 once a week.

Should a relapse, or a re-infection (which is most unlikely) occur while the patient is under this treatment, the whole course is to be commenced *de novo*.

These rules are general and not specific. The quantities mentioned are what one considers the average patient should take. Some will require more, others less. There are many factors entering into the circumstances of cases of malaria that will necessitate some modification of this method. Amongst these are the freshness of the infection at one end and chronicity at the other, inordinate sensitiveness to the toxins metabolised by malarial parasites, unusual susceptibility to the effects of quinine, quitting the malarious for a non-malarious locality, etc. It is not possible to formulate any rules for quinine administration for three months that would cover the peculiarities met with in all patients.

The parasites of malaria, when they have once increased to sufficient numbers to produce malarial fever, are difficult to get rid of permanently. One, personally, believes malaria to be one of the most difficult of infective diseases to eradicate. Nothing short of a three months' course during the non-malarial season, and a *four* months' course (including one month's prophylactic use) during the malarial season (when it is assumed re-infections are repeatedly occurring), is sufficient for this purpose.

There is an essential difference between the curative use of quinine in cases of known malarial infection, and that of its use as a prophylactic. In the former case there are already hundreds of millions of malarial parasites in the blood ; in the latter when successfully carried out, even when, as may be the case, infection is continuous and repeated, the number of parasites rarely reaches the proportion of one in half a million red cells. Literally, all use of quinine in malaria is curative, for it is employed to kill parasites that have entered the blood through anophelines. The term *prophylaxis,* as applied to quinine, signifies prevention of malarial paroxysms.

There appears to be some apprehension that quinine may give rise to blackwater fever. This apprehension to the use of reasonably large doses in malarial fevers, in this country at least, is unfounded.

Of the large number of cases of malaria investigated in Military and Civil Hospitals during last year, there was only one case that could be diagnosed as blackwater fever. It was the case of a Garhwali coolie in the Sudder Bazar Hospital, Chakrata, who had suffered for many months from recurrent attacks of malignant tertian fever, had a very large spleen, was intenselv anæmic, and had suffered from hyperpyrexia, severe bilious vomiting, hæmoglobinuria and suppression of urine, acute pain in the loins, etc. After recovery from the initial attack every time he got quinine by the mouth an attack of hæmoglobinuria was precipitated. Intramuscularly in small doses it did not affect him. The man acquired his malaria in the Pauri District in Lower Garhwal. Assistant Surgeon Twells informed me of another similar case treated in the Chakrata Sudder Bazar Hospital which proved fatal—the man came from the same district.

(*a*) Eradication of Malaria from the entire Population by Quinine.

Cinchonisation of all infected persons in a community has been tried on a large and on a small scale. In the former it has been successful in a number of malarious places, and in the latter in many instances, especially when the cinchonised persons in these malarious places are shut off from connection with infected persons.

Theoretically general cinchonisation of infected is sufficient.—Cinchonisation of all infected members of a population should *theoretically* be sufficient to eradicate malarial fevers. The principle aimed at in this use of quinine in a malarious district is the extinction of malarial parasites from all who are infected. When carried out in its integrity, we assume that, with some reservation, the parasites of malaria in the blood of all inhabitants are killed off. It would follow that, even in a malarious district with myriads of anophelines, if there were no parasites in man, the bites of these gnats would be harmless. The exception referred to is that of malarial parasites latent in internal organs but absent from the peripheral circulation. General cinchonisation is, as far as the entire population of India is concerned, impracticable. The foundations of this method are—(1) ascertaining which persons in the community harbour malarial parasites in the blood, and (2) eradicating these parasites by the periodical administration of quinine for a period of three months. The acquisition of this knowledge would mean the examination of the blood of the entire population which in this country is a physical impossibility. Even were it possible, the entire output of quinine in the world would be insufficient to cinchonise for three months all cases of malarial infection in this country. Nevertheless the method is not without its place in India, for it is applicable to many groups of men under discipline and control when all imported cases of malarial infection can also be cinchonised. One case in which it is specially applicable is that of all children living in military cantonments who are the chief source of malaria to the troops of our whole Army in India. In a later section one has given the details as to how eradication of malaria by quinine can be carried out in children in cantonments.

Disadvantages of general cinchonisation of infected.—In Koch's method of general cinchonisation in German East Africa, quinine had to be given to all infected persons in the district on two consecutive days for three months, at first twice a week, and then every 10th and 11th day. Koch's special means of cinchonising on a large scale all infected persons is, as far as India is concerned, impracticable. This method has certain disadvantages. Parasites may not be found in the peripheral blood and yet relapses of malarial fever take place. The same may be stated regarding its impracticability in a large town or city, or any extensive civil community. Such a measure requires a large staff of medical men and an almost unlimited supply of quinine. The compulsory use of quinine is also impracticable, and its adoption by legislative enforcement would defeat its own end.

The complete eradication of malaria from the human system by quinine takes a considerably longer time than that during which quinine treatment is practised in our hospitals in India. "To extirpate the parasite in a patient demands, let us say, four months' assiduous cinchonisation, and in very malarious towns a large percentage of the natives and nearly all the children may be infected. To deal with these would require a heavy annual expenditure for medical attendance and quinine with examination of immigrants." *

One of the great drawbacks to the general cinchonisation method is that there is a constant influx of immigrants, many of whom are harbouring malarial parasites. Especially is this the case in large towns, where people from the country are constantly coming in to their daily work or to market.

*Ronald Ross in Allbutt and Rolleston's *System of Medicine*, Vol. II, Part II, p. 286.

Communities to which applicable.—In the case of troops, policemen, Government officials of all classes, gangs of coolies on canal and road work, railway embankments, artisans in factories, railway servants, all organised groups of men under discipline and those of controlled institutions, there should be no difficulty in enforcing general cinchonisation, if this is thought to be necessary. It can also be carried out with some facility in small communities. Officials in malarial districts, in addition to taking quinine themselves prophylactically, may do much to teach the poorer classes the principles of malarial prophylaxis.

Relative immunity of persons living in endemic malarious places.—The natives of malarial districts acquire a partial, never an absolute, immunity to malarial infection, just as those born and living in the epidemic zone of yellow fever acquire a partial immunity. It is supposed that the long action of the malarial poison on the system in endemic malarial centres gives the inhabitants time to acquire the degree of resistance necessary to create a partial immunity at least. Such immunity as natives possess is probably due to the fact that in childhood they suffered more or less constantly from malarial infection, from which practically no children in malarious localities escape. It has been suggested that the use of quinine constantly as a prophylactic precludes the possibility of the system acquiring immunity from malaria, as the defensive forces of the white blood cells and blood plasma under its influence are never given a chance to operate. Hence the plan advised by some authorities of giving only sufficient quinine in small doses to protect against a serious manifestation of malarial infection, and thus after its prolonged administration bring about permanent immunity. This is the basis of PLEHN's method of quinine prophylaxis.

(*b*) QUININE PROPHYLAXIS OF MALARIA.

Methods of administering quinine prophylactically.—There are various methods of administering quinine prophylactically, and medical officers of the Army in India have unfortunately abundant opportunities of testing their value.

Koch's method.—KOCH's *method* consists of what is known as the "long interval prophylaxis," by the giving of 15 to 22½ grains on two consecutive days at intervals of from 8 to 11 days, usually on the 10th and 11th day.

Celli's method.—CELLI's *method* consists in the daily administration of two sugar-coated tabloids of 3 grains each of the bisulphate or hydrochloride of quinine.

Plehn's method.—PLEHN's *method* of "double prophylaxis" consists of giving 7 to 8 grains every 4th and 5th or 5th and 6th days.

Indian method.—A large number of medical officers in India now give a medium-sized dose (10 grains) twice a week on two consecutive days.

Method here recommended.—While we have no positive statistics or extended experience to guide us as to the best method of using quinine prophylactically, such as we do possess appears to indicate that the maximum influence of quinine as a prophylaxis is best obtained by giving 5 grain doses daily (with a 10 or 15 grain dose once a week) or 15 grains twice a week on two consecutive days during the malarial season. I would recommend that in stations where malaria is comparatively mild, 5 grains be given daily; where it is moderately severe, 5 grains daily for 6 days and 10 grains on the 7th day; and where severe or very severe, 5 grains daily for 6 days and 15 grains on the 7th day.

Prophylaxis by quinine is now adopted in practically all jails in this country and amongst all troops. It is also in vogue amongst the greater number of Europeans residing in endemically malarial places. The extent of its practice by the rural population is unknown, but in all probability it is exceedingly limited—even when quinine is available few village natives will ever take the drug unless actually suffering from malarial infection.

Wherever quinine is being issued prophylactically to bodies of men, its use should be rigidly controlled and issued directly under the supervision of some responsible officer. The prophylactic use of quinine is not as a rule popular, and all possible forms of evasion are practised by those who dislike it.

Whenever quinine is used prophylactically or curatively *it should be given regularly*, as it appears to be a well recognised fact that when taken irregularly, especially in small doses, it, for some undetermined reason, seems to lessen the resistance of the organism to malaria. This is possibly due to the parasites of malaria being immunised to its effects, and being then able to continue their evolution in its presence, as occurs with the *Trypanosoma gambiense* after a time under treatment by atoxyl. This irregular use of quinine and the effects therefrom are responsible for the statement that quinine has no influence in checking malaria, whereas it is not the fault of the quinine but the manner in which it is taken.

When smaller doses fail as a prophylactic larger doses are necessary. The dose that is necessary varies in different districts. We cannot get outside the fact that quinine is a true disinfectant of the blood as regards malarial parasites when given in appropriate doses.

Many medical men in India consider that quinine has no effect as a prophylactic in malaria. The cause of failure is usually either in the dose, method of administration, or want of supervision. In no instance that has come under one's personal observation has there been failure when the drug was employed so as to obtain its full prophylactic influence.

It is impossible in any case to state that the prophylactic issue of the drug has done no good unless control observations are made at the same time. While the comparison of one year's cases with those of another is in a general way useful, it is open to many fallacies, chief amongst which is the varying ways, periods, and forms in which the quinine is given; it is seldom that the issues on two consecutive years are precisely identical—*e.g.*, regiments may move from a healthy to a malarious station, or *vice versâ*, change in the method as regards diagnoses, *e.g.*, say in 1907 or 1908 a large proportion of malarial cases were detained for a few days, while in 1909 every case of malarial fever was admitted; and so on.

For comparisons to have any weight they must be rigidly local, for not only does the intensity of malaria vary in different parts of communities and different regiments in the same station, but in many cases in particular quarters of a bazar and different companies of the same regiment, and one has found that such variations in intensity largely depends on the relative positions of breeding grounds to infected and susceptible people.

I am indebted to Dr. Courtney, Civil Surgeon, Hissar, for the following interesting account of quinine prophylaxis in the Hissar Jail during the last few years:—

"From 1st January to date (17th December 1909) I have had only one case of true malarial fever in this jail. This is a record for this jail as will be seen from a comparison with previous year's figures:—

	Average population.	Admission for malarial fevers.
1904	169	131
1905	168	73
1906	182	75
1907	164	14
1908	185	1

"This satisfactory result I can attribute safely to quinine and to quinine alone. I have, no doubt, continued the sanitary improvements in the jail buildings as regards ventilation and drainage, and filling up and levelling depressions in and around the jail, but this of itself is not, in my opinion, sufficient to account for the satisfactory result recorded above.

"In 1907 quinine was also issued as a prophylactic in this jail, the result, as shown above, was a distinct and decided improvement; the admissions for malarial fevers being, with an almost equal daily average population, about one-fifth of the previous year's figures. I am now convinced, however, that that result would have been better but for the reason that no real supervision was exercised over the issue.

The issue was made every sixth day and hence had to be entrusted to the Hospital Assistant, as I could not be present at each and every issue.

"I must here confess, in the interest of science, that although I firmly believed in the mosquito theory of malaria, I was somewhat sceptical as to the value of quinine as a prophylactic without the aid of mosquito-nets as protectives. The result of last year's experience, however, converted me absolutely as to the prophylactic value of large periodical doses of quinine, and I determined that in 1908 I would give the drug a fair and impartial trial, and the result, as shown above, has exceeded my utmost expectations.

"In 1908, I was able to carry out this decision quite easily, as, according to later orders, the issue was to be made weekly, at the Monday parades, instead of every sixth day. At these parades, a 15-grain dose of quinine was given to each and every prisoner in my presence, women getting 10 grains. The prophylactic issue was begun on 3rd August and has been continued regularly ever since.

"To keep the jail free of malarial fevers, I gave every prisoner, admitted to jail after 1st January 1908, a 10-grain dose of quinine on admission, irrespective of whether he was a convict, under-trial or civil prisoner. During the malarial season this dose was given irrespective of the weekly 15-grain dose. This 10-grain dose was also issued in my presence in the jail office where all new prisoners are brought up before me the day after their admission, and the procedure has been rigidly followed throughout the year."

"The periodical issue of large doses of quinine is undoubtedly 'the' preventative for malarial fevers, but its issue must be minutely supervised, as the natives of India are prone to shirk the dosing by any and every means in their power. Nor can its issue be entrusted to subordinate officials, as they do not yet realise the benefits of the prophylaxis, and carry out the issue as a matter of routine without taking any interest in it.

"No anti-mosquito campaign was undertaken this year in this jail."

Sale of pice-packets quinine in India.—The sale of quinine in 5-grain pice-packets is very largely in operation in India at the present day, and is doing a certain amount of good. Unfortunately the sale is liable to abuse. There have been numerous suggestions as to the best method of controlling the sale of quinine, such as the employment of special men who would travel with it from village to village allowing them to make a certain percentage of profit on the sales effected, or the exclusive sale in police *thanas* wherever these are established. sale in post offices, by schoolmasters, in kutcheries, etc. Special endeavours should be made to enlist the interest of merchants and others to sell quinine and explain its value to the people. The Government in this cheap sale of quinine is undoubtedly effecting some degree of mitigation of malarial infection in the remoter parts of districts.

Sale of packets of quinine containing 12 doses.—Instead of pice-packets it would be much sounder to sell packets containing at least 12 doses of quinine, so that the purchaser would be able to take a short course of quinine treatment.

It cannot be stated that we have so far arrived at any definite conclusion from our Indian experience as to which is the best way of administering quinine prophylactically. Small groups of statistics have been published from various districts in which the endemicity has differed widely, the conditions under which the drug was given were not identical, the figures have usually been small and control observations have not been made. Yet the question is one which in malarial districts could be solved without much difficulty, especially is this the case with troops, and in jails.

Naturally the object in quinine prophylaxis is to achieve the desired result of preventing malarial fever with the minimum expenditure of quinine given in the most practicable way. Whichever method is adopted it should be adhered to consistently. That chosen will, of course, be the one compatible with all the local conditions to be dealt with, the amount of responsible supervision that can be given, and control over the recipients of the drug being important factors. The plan to be adopted having been chosen, the length of time it is to be carried out is fixed, and a formula of procedure as to the administration of the drug worked out.

Whilst there is so much difference of opinion as to the best method of using quinine prophylactically, it would be well that the question be subjected to a rigid investigation. There are facilities for carrying out such an investigation in this country not met with elsewhere. Endemic malarial areas should be chosen and bodies of men in them should be administered quinine in various ways, control observations being made at the same time. Groups of statistics, amounting to at least an aggregate of 5,000 each, would decide the question once for all. with only a small margin of probable error. The conditions of each group as far as prevalence, intensity and liability to relapse, and as regards hygienic condition of the people, etc., should be as nearly identical as possible. We would then get a fairly correct record as to the relative prevalence of malarial fevers among persons taking the drug in these various ways, and those not taking it at all.

A difficulty which has sometimes to be contended with in the administration of quinine is the prejudice against it entertained by many natives, which is only part of the antipathy they have to all medicine.

One of the prejudices entertained by the natives of India against the use of quinine is based on the theory that malarial fever is a "cold disease" and should be treated by a "cold remedy," while quinine is considered to belong to the opposite category of medicinal agents.

The rationale of the methods of administering quinine prohylactically differs. When quinine is given in *small doses* at frequent and regular intervals. the object aimed at is to keep always in the blood a certain amount of the drug, so that when malarial parasites commence multiplying after being injected by anophelines, they are rendered *hors de combat.* It is very doubtful whether sporozoites are affected by quinine before they enter the red blood cells. In this method the minimum quantity of quinine that can effect this desirable object is used. Its weak point is the probability that the drug will be forgotten or not taken for some reason one day, and then the parasites may gain the upper hand, as when they have once got a foothold in the blood small doses may not eradicate them. Quinine does not prevent malarial parasites gaining access through bites of anophelines. Quinine when present in the blood in sufficient quantity simply renders malarial parasites harmless when they are injected, by preventing the initial schizogonous cycles.

In the *large dose method*, that of giving large doses at intervals of some days, the object is to have the drug in the blood in such a degree of concentration that malarial parasites, should they meanwhile gain access and begin their schizogonous cycle, are quickly and easily killed; the parasites even at the end of the intervals between the doses are in such few numbers, and so easily assailed in their sporulating stages, as to be readily killed. On the whole, the object arrived at is attained in both methods in the same way.

We know of course that quinine is fairly rapidly eliminated from the system. and that by the end of the interval in the large and infrequent dose method, there is practically none in the blood. In the small dose method there is always a certain amount ready in the circulation.

The small dose method is the more ideal way and simulates the form of acquired immunity, but is not, in endemic malarial places, relied on by many medical men, because from some accident the dose is not taken, and in the meanwhile infection may occur and then these small doses are insufficient to eradicate the parasite.

Those who advocate the 5-grain dose daily hold that by this method the quinine is always in the blood in sufficient quantity to kill any parasites reaching it, and yet not sufficiently to produce cinchonism. Further they consider that the curative effects of quinine, when malarial fevers do occur, is not lessened from the system being accustomed to the smaller doses.

It is to be remembered that the small dose methods do not affect the occurrence of relapses ; no ordinary prophylactic doses do this.

Quinine not literally prophylactic but curative.—Quinine cannot be regarded literally as a *prophylactic* against malarial infection, as it does not affect the entrance of the parasite into the blood, nor does it prevent the first stages of the development of sporozoites in the blood, and it is very probable that it does not prevent these latter infecting red blood cells. The drug weakens or kills the parasite after it has infected the red cells and at the moment spores are set free from red cells.

We cannot lay in a reserve stock of quinine in the system ready to attack malarial parasites when they arrive. All experience indicates that this is a useless waste. Quinine administration during a pre-epidemic period is of no use as a prophylactic measure. It is best to start its use as soon as the risk of malarial infection arises.

It has been shown on a small scale that 5 grains of quinine every day reduces attacks by 20 per cent. ; 10 grains daily by 56 per cent. ; and 15 grains a day by 70—80 per cent. But even 15 grains daily does not always prevent malarial infection, and when infection as shown by paroxysms has occurred, larger doses may be needed. When malarial infection has already occurred, and the parasites are multiplying in the blood, it is no use giving small doses.

One has used quinine prophylactically against malarial infection in large bodies of men for many years, and it has never in one's experience given rise to accident, except, in a few cases slight indigestion, headache, or deafness, all temporary and passing off in a day or so.

Quinine does not act on sporozoites.—Notwithstanding statements to the effect that quinine acts on all stages of the malarial parasite in the blood, it is probable that it does not do so until after the parasite actually attacks the red blood corpuscles. As far as we know the earliest form in which the malarial parasite enters the human blood is that of sporozoites (elongated, needle-shaped, actively mobile bodies), which are injected into the blood vessels from the salivary glands through the proboscis of malaria-bearing anophelines. These sporozoites are probably not affected by quinine in the blood.

CRAIG'S opinion on action of quinine.—C. F. CRAIG, after a careful study of the action of quinine on malarial parasites in fresh and stained specimens, records the opinion that it affects the parasite injuriously during all stages in man except just prior to sporulation, at which time the sporulating body is not affected and sporulation occurs, but most of the spores are destroyed by the drug in the blood plasma. One can from personal observation fully endorse this statement. He advises giving quinine in divided doses at regular intervals of time rather than in one or more large doses at long periods.

Economic value of quinine administration.—As an economic result the administration of quinine prophylactically is well founded. "In Sardinia the expenditure of 3,500 *lire* in quinine has resulted in a saving of more than 10,000 *lire* value in days' work ; of course no account is taken of our *future* good resulting from this diminution of fever, it merely refers to the net economic result of one year's operations." *

Celli records that in 1904, out of a population of 70,000 persons in malarious districts in Italy protected by routine quinine administration, only 8·08 per cent. suffered from malarial attacks, and this in a bad fever year. "In a particular district, in the lower valley of the Aniene and Tiber, amongst 578 persons treated regularly by quinine, there were 12·10 per cent. of cases ; in 270 persons treated irregularly there were 50 per cent. of cases, and amongst the central population not treated at all, there were 46·52 per cent. of cases. Again in 1905 in the valley of the Aniene (which is very malarious), of 419 treated prophylactically only 3·81 per cent. of cases occurred. In the notorious Campagna of Rome, in 1900, when no medicinal prophylaxis was carried out, malaria prevailed to such an extent that 31 per cent. of the population suffered from attacks of fever ; in 1904 quinine commenced to be given systematically, and in this year 26 per cent. were attacked. The figures for the three succeeding years were 20, 11 and 10 per cent. respectively ; and in 1905 only 5·1 per cent. of the population suffered."

In connection with the use of quinine in India one would recommend—

1. A considerable extension of our indigenous cinchona plantations, and of the machinery for the manufacture of quinine, so that the output of the drug would not only be larger, but made cheaper. The present output of indigenous quinine, plus that imported, would be insufficient to meet the requirements of a generalised free distribution to all infected persons, even if we limited such distribution to the more epidemic malarial districts.

Reduction in price of quinine an urgent requirement in general prophylaxis.—Cheapening the price of quinine is probably the most urgent necessity in the general prophylaxis of malaria in this country. At the present time the wholesale price of quinine made in the Calcutta and Madras Quinine Factories is higher than that of the larger private chemists in this country.

* Celli's *Malaria*, p. 188.

Private firms collectively import about twice the quantity made in the Government factories. The average annual output from Government factories is about 40,000 pounds. This is the produce from about five millions of cinchona trees, including those grown in the Darjeeling and Nilgherry Plantations.

The smallest quantity of quinine that could produce any appreciable amount of good in the general population during epidemic times is about 3,500 pounds per million of people. Even this amount would only partially treat the actual malaria cases that occur during such periods. There are probably over 80,000,000 cases of malaria annually in this country. These facts lend support to the suggestion made above as to the necessity of increasing the output of indigenous quinine and lessening its price. It is not considered that this could adequately cope with the requirements of a widespread epidemic of malaria in India—the whole output of quinine of the world would not do this. What one wishes to point out is that our present output is insufficient to meet the ordinary requirements of an average year were anything like a widespread distribution attempted. As cinchona trees do not yield bark for some years after being planted, it will be some time before a sufficient quantity of quinine can be regularly manufactured, even supposing that the cinchona plantations in this country were at once considerably extended.

2. The establishment of a staff of quinine distributors independent of the issue of the drug through school-masters, post-masters, and other officials, in all districts in which malaria is epidemic or threatening to be so. This staff should be taught how to diagnose and treat cases of malarial fever, malarial enlargement of the spleen and malarial anæmia, and how to give quinine both curatively and prophylactically to all persons in villages (and if necessary in towns) suffering from malaria, and in each village leave a supply with the headman of the village to administer to those requiring it during the interval between these visits. The strength of the staff so required would be worked out by the authorities in the different provinces.

Failing such a staff, arrangements might be made to ensure that every village headman in severe malarial districts receives a certain quantity of quinine in powders, pills or tablets periodically, the quantity being determined by the population he controls. School-masters and post-masters exist in comparatively few villages, but there is a *mamlatdar* (*patel* or *patwari*) in every village, and he is a responsible man and one of some importance and much influence in his own little territory.

The only form in which this distribution would be popular is in pills, tablets or powders. Pills are unreliable when not made up fresh. The machinery in India at present is inadequate to manufacture even one-tenth of the tablets that would be necessary. The quinine tablets, pills or powders should be made up in the Government Medical Stores, quinine factories, or in the larger provincial jails. Quinine should not be given in bulk to members of the distributing staff. One would include as part of the duties of this staff, the diagnosis of malarial fevers in villages, recording the malarial statistics of villages, and forwarding them to the Civil Surgeon of the District, in the same way that vaccinators now keep up their vaccination registers. Such statistics should be prepared and despatched weekly; this would keep the malarial statistics and the work of quinine distribution regularly under the eye of a responsible medical officer.

These dispensers would distribute quinine among the sick by house to house visitation. When this is carried out the particular towns and villages to be included should be definitely laid down and shown on the map of the district. They should be all time men, live in a convenient centre of the town, or when in a rural district, in a central village. They should be provided with havresacks to contain tin canisters of quinine tablets or pills, which should be ½, 1, 3, and 5 grains each, each canister to contain one kind of tablet or pill only; when one grain doses are required two half-grain tablets would take their place. He should offer the quinine gratis to all persons with enlarged spleen, and all persons with any form of malarial fever. They should not demand or take any payment whatever for medicine or his advice. In cases of active malarial fever he should advise two pills (dose, according to age) to be taken every morning just before the morning meal, giving enough quinine to each person for a week.

The dosage of these tablets or pills should be —

Years	...	1	1—3	3—6	6—9	9—12	over 12
Grains	...	½	1	2	3	4	5

He should visit the more malarious places most frequently—the number of visits and details to be specified to the Civil Surgeon of the District.

These men should be thoroughly instructed in their duties, they should be taught the general nature of malaria, its mode of spread and the methods of diagnosis of the ordinary forms of malarial fever. Each should have an official badge and be provided with a small pamphlet detailing their duties, the method of using quinine, and they should report the work carried out to the Civil Surgeon of the District.

The preparation and despatch of the quinine pills, tablets or powders should be in the hands of the Medical Department and not in those of the distributors of quinine. One recognises that in an organisation of this kind in India there would almost certainly be a leakage, but every possible effort should be made to control this. When the issue of the drug is free, there would be no further market for it, at least not in rural districts.

One fully recognises that the expenditure on quinine alone, if it reached all cases of malaria of this country, would be enormous, and, as previously stated, the supply of quinine of the whole world would be insufficient for the purpose.

Junior Hospital Assistants would form an excellent foundation for such a staff, and they would, in addition, be able to take the spleen index, general spleen rate, make observations on the distribution of anophelines and the breeding grounds of anopheline larvæ, and carry out the duties of mosquito inspectors.

The foregoing is a modification of the system of quinine distribution recommended by Professor RONALD ROSS for the Mauritius.

It is fully recognised that such a distributing staff could only be employed on a small scale and in the presence of an epidemic or threatened epidemic ; but as in each province there are localised epidemic foci practically every year, these men could be transferred from one place to another as occasion demands. Their work during the malarious season would be severe, but should not cease at the end of that season, as there would then be a large number of cases of relapse to deal with which would go on until the next malarial season.

What appears to be necessary is that a staff of quinine distributors be employed who would be constantly moving about in the more malarious parts of districts, who would, as it were, act as the dispensers of itinerant dispensaries. These men would, during their trips to villages, endeavour to explain to the people the way to prevent malaria, and how quinine should be used when infection has occurred.

In the absence of a definite staff of quinine dispensers, the method of distribution would vary in different districts. In the United Provinces the method of free distribution of quinine in epidemic malarial districts in 1909 was roughly as follows. The decision as to whether an epidemic was present was based on the average normal attendance of malaria cases at hospitals and dispensaries during the months of August, September and October for the last five years ; if for three weeks during these three months in 1909, the average attendance was double the normal attendance, a severe epidemic was considered to be present in the locality. The Provincial Government was then informed of the fact and the quantity of quinine required indented for. The actual quantity of quinine required was determined by the Civil Surgeon in consultation with the Deputy Commissioner or other District Civilian of the locality. The average quantity used varied, the maximum being from 1,000 to 1,500 pounds per million of people. The quinine was made into 3- and

5-grain pills by vaccinators and jail labour (chiefly the Aligarh Jail). They were put up into boxes containing 250 pills, two of these boxes being considered sufficient for 100 persons. In the distribution there was the co-operation of all officials of the district, each of whom got a supply of pills to distribute personally in the villages allotted to them. The primary responsible agencies for the distribution in villages were the District Boards, each of which prepared a list of all the headmen of villages under their control. The villages in the district were divided into circles, each circle was placed under an official or a member of the District Board, whose duty it was to distribute the quinine in person to all village headmen in the circle allotted to him.

Before the distribution was made all officials to be engaged in the work (tahsildars, naib-tahsildars, kanungos, ahlmads, officials of the Opium Department, members of District Boards, sub-inspectors of police, bakshis, school-masters, pound-keepers, and every other available official) were assembled at a central place in the district, and made to thoroughly understand the object aimed at. They then received their quantity of quinine and went to their allotted villages and distributed it, usually completing the distribution in two or three days. In handing over the boxes of quinine pills to *patwaris*, the official explained the method of use. Each hundred persons infected with malaria were first to get 200 pills and subsequently the same hundred to get 250 pills In districts where the infection was not severely epidemic, the quinine was sold in pice-packets, each packet containing three .5-grain tablets. The agency for the sale of quinine in these latter districts was quite distinct from that in which the quinine was issued gratis.

Anterior to this distribution a committee had worked out the method of distribution and the approximate quantity that should be issued gratis. This committee arrived at the conclusion that the quantity of quinine necessary to make any serious impression on an epidemic would be an average of 50 grains per head. In a district of a million people this would mean about 7,000 pounds of quinine at a cost of about ten rupees per pound. It would be impossible to procure and pay for such a large quantity, and equally so to distribute it and get the people to use it when distributed.

Modifications of this method of distribution have been adopted in various districts in other parts of India. In Lower Bengal Hospital Assistants were largely made use of in the distribution.

B.—Segregation of the Healthy.

A comprehensive principle in malaria prophylaxis is the keeping of healthy persons isolated from those that are infected with malarial parasites. This has reference specially to the keeping of native children of malarious places away from the community we wish to protect.

"For troops and officials segregation is always useful, and the detection and treatment of the sick must be urged whatever other methods are employed, because otherwise, even if local infection be absolutely abolished, a number of relapses will occur among old cases for years to come."

If healthy persons in an infected area were absolutely protected from mosquito bites, fresh infection would not occur. Healthy residents outside the infected locality and within the range of flight of infected mosquitoes coming from it, should also be completely protected from mosquito bites. The same applies to all persons coming to the locality, even for a single night. This measure is *segregation of the healthy*. Most of the malaria acquired by Europeans in this country is got through anophelines that have been infected by natives, especially personal servants, suffering from malarial fever. This is not always obvious as the servant may have been ill some weeks previously and the incident may be forgotten. It must be remembered that the malarial parasite takes roughly ten days to develop in the mosquito and another ten days to multiply sufficiently in the infected person, before malarial fever shows itself. Hence aside from any question of humanity, it is well to be on the watch for fever amongst servants, and to dose them properly with quinine when it manifests itself. In using quinine with servants one should always give it oneself, preferably in the liquid form. The mere putting of some quinine in a packet and telling him to take it at definite times is not sufficient. Often he has no faith in it, or he dislikes its taste or its effects, or is apathetic about such a minor trifle as ordinary *tap* or *bukhar*.

The method of segregation of the healthy is applicable to comparatively small bodies of men such as our garrisons in India, troops, gangs of labourers, jail prisoners, and Government employés occupying isolated groups of buildings.

Wherever possible, it is desirable that bazars and families with native children especially, should live sufficiently remote from all troops and Europeans to render malarial infection improbable in the latter from the former. It is well known that in different malarious districts from 10 to 100 per cent. of children under 10 years of age harbour malarial parasites in the blood, and they do so when in apparent health. Native huts and quarters generally are the chief sources of infected anophelines, and native children under 10 living in bazars and native quarters are the chief sources whence anophelines get their infection. Troops in India, we know, often acquire malarial infection in the bazars, in stations where there is a practical absence of anophelines in cantonments. Even in officers' quarters there are necessarily a certain number of servants in the close neighbourhood, and frequently the latter have their families with them, so that in malarious places we are constantly in the vicinity of infection, as the chances are that there are anopheline mosquitoes in or about our servants' houses.

The segregation method can of course be applied by any one who has the facilities for doing so. Natives who have the means and wish to do so, may equally, with Europeans, isolate themselves from the infected population of malarious areas.

There are numerous instances in which the plan of segregation of Europeans can be carried out with comparatively little cost, especially is this the case when such radical measures as extensive and costly drainage schemes cannot be undertaken. For example, the removal of a few native huts, or a bazar, or even a village on the confines of barracks or cantonments, may make a marked alteration in the health of troops. Moving troops into tents, a fortnight or so after the rainy season has begun, and away from bazars, is another method which may be successfully adopted in some stations.

C.—Isolation of Infected Persons.

As part of the general principles governing malarial prophylaxis, it is important that mosquitoes be prevented from biting persons infected with malaria. In this matter personal efforts are of little avail—all one can do is to recognise and act on the principle that a case of malarial fever is as much a danger as a case of any of the eruptive or infective fevers. It is our duty to endeavour to limit the number of such cases amongst our personal servants, for if one or more of these are infected, their proximity renders us liable to infection through the anophelines they infect. In a general way it may be said that when malarial fever occurs in Europeans, the latter has acquired it from mosquitoes that have previously bitten an infected native, often one's own servants or their children.

Isolation of those infected by malaria is to some extent now carried on in most of our large hospitals in India, and in many of our smaller hospitals also. As a general prophylactic measure, however, it is, as far as one can at present see, impracticable. The children of the poorer classes, who are the most prolific sources of malaria, cannot be isolated. Nevertheless, with all these difficulties in connection with isolation from mosquitoes, it should be adopted as far as practicable.

Theoretically, and when carried out in their integrity, both segregation of the healthy and isolation of the infected as anti-malarial measures, require careful and repeated examination of the blood of all persons in the place and of all persons coming to it. There are many difficulties in this. The blood of infected may show no parasites, or may have them only during relapses. Many are infected for years, so that isolation is impracticable in their case.

In an endemic malarial locality in which we find both malarial fevers and anophelines, if infected persons are shut off from attack of anophelines, and thereby prevented from inoculating the healthy inhabitants with malaria, malarial fevers would die out. To effect this, infected persons should be isolated until all malarial parasites (including of course gametes) have ceased to be found in their blood. All infected persons outside the town, station, etc., within the mosquito range of infectivity should also be isolated. Theoretically we may say that as soon as cases of malarial fever are diagnosed, they should be isolated in the same way as groups of any other infectious fever are. Malarial fever is a typically infectious fever, infection being caused by anophelines. All persons suffering from malarial fever in a malarious place are a source of danger to others.

Segregation of the sick from the healthy requires large hospitals, and hospital establishments, the use of mosquito nets or wire-gauge doors and windows, etc. The long-continued infective period of malaria renders legislation as regards compulsory notification and isolation impracticable. Where only a few cases occur, isolation is quite easy. By general isolation from mosquito bites both methods (segregation of healthy and isolation of infected) are united.

Isolation from mosquitoes cannot of course be in any sense a complete protective measure. We all have to work out of doors, often in places where anophelines attack us, and the poorer classes who have to work and live at all times without adequate protection are specially liable to be attacked. Again, even where they can be afforded, wire-gauze screens and mosquito nets get out of repair and permit of mosquito attacks. Nevertheless the principle of isolation from infected persons and from mosquitoes is sound, and whenever practicable should be carried out.

D.—Protection against Adult Mosquitoes.

A considerable part of the prophylaxis against malaria is embraced in protection from mosquito bites. To defend ourselves from the bites of mosquitoes, mosquito-proof wire-gauze rooms and wire-gauze screens to doors and windows to houses, and by mosquito nets, must, to a large extent, lessen the chances of malarial infection.

(*a*) Mosquito-proof Houses.

Protection from the bites of mosquitoes by wire-gauze doors and windows is known as Professor Celli's *method*, and consists in causing houses to be impenetrable to mosquitoes by closing all openings with wire gauze having a mesh of about 12 strands to the inch All windows and all doors that are not absolutely necessary for ingress and egress are closed permanently by frames covered with wire-gauze, and all indispensable exterior doors are fitted with double spring doors of the same material, these two doors being sufficiently far apart to allow of closure of the first door before the second is opened. A very important part of this system is that the doors should be self-closing, this automatic arrangement being effected by springs. Where there are upper storey rooms for sleeping in, there should also be a wire-gauze door at the bottom of the staircase. A mosquito-protected house is, theoretically, the ideal method of excluding mosquitoes, but it embraces some initial outlay, as well as care and a state of education in hygienic matters which all classes of the community do not possess.

Mosquito-proof houses for India are, on the whole, one of the cheapest general methods of preventing malarial infection through anophelines, and they are certainly a great protection in all endemic malarial areas. The wire-gauze method is one that is specially applicable to private dwellings in this country. If carried out in its integrity, it gives complete immunity to the occupants while indoors from the attacks of mosquitoes, and that even when the breeding grounds are in the near vicinity. Further, it renders the occupants independent of their neighbours' neglect as regards breeding grounds of anophelines. It is a method that is, so far in this country, used to only a limited extent.

There are thousands of bungalows all over India, such as Government dâk bungalows, rest-houses, circuit bungalows, canal bungalows along irrigation canals in malarious districts, in which there is no other practical method except that of using wire-gauze doors and windows or mosquito nets, of preventing the attacks of mosquitoes, and of the two the former is decidedly the better. It is also highly desirable that all barracks, hospitals, and all official quarters in malarious districts be provided with this wire-gauze protection.

The reports of the success of this method of protection indicate that its usefulness is no longer a matter of doubt. It is now adopted in many malarious countries—one has recently seen it successfully used in Queensland, Hong-kong, Southern Japan, China, the Philippines, California, Mexico, Arizuna, etc., and, to some extent, in India.

Mechanical protection by wire-gauze to houses, of course, leaves the occupant liable to accidental infection by anophelines once he is outside the protection thus afforded.

When it is not possible to have wire-gauze doors and windows all round the house, they may still be useful when applied to bed-rooms and verandahs.

In the mosquito-proof bed-room there is a wire-gauze screen room which fits within the bed-room, and in the centre of this, the bed is placed. It is provided with a door and a light may be kept in it, and even an electric fan or a small punkah. It can be so constructed as to be movable, and be taken down every morning if necessary, or it may be put up as a permanent structure.

An adaptation of the wire-gauze room for sleeping outside the house on the plains, or even as an outside dining-room, would be a welcome innovation, and in towns and cantonments where there are electric fans, would be very comfortable.

Another modification of this suggestion is a portable mosquito-proof bed-room sufficiently large to hold the bed, a table for a lamp, and, if necessary, a chair. This is, however, somewhat bulky, and is liable to require repeated repairs if carried about. As a permanent fixture such a room, when provided with spring doors, affords absolute and permanent protection against mosquitoes once oue is in it.

Various forms of wire are used—tinned wire, copper, brass and nickel wire, and plain iron wire. Tinned wire-gauge is very useful, and is the most inexpensive; copper and brass wire are 1½ times the price of tinned wire. In estimating the cost of course, we have to include the construction. As a rule such screens are most comfortable; they keep out insects and help to keep out damp. They are specially indicated in all public buildings and in the better class of private houses. They are at present impracticable in the poorer clasess of dwellings.

In the absence of wire-gauze doors and windows, the covering of all openings with some simple form of mosquito netting or *muslin* fixed to the doors and windows may be adopted. Muslins are manufactured all over India, are very cheap, and it is possible to cover all the required doors and windows in a large house with it for a few rupees. It cannot, however, be said that these fragile window and door coverings can replace the more permanent and effective wire-gauze fixtures to windows and doors.

The experiment of LOW, SAMBON and REES, in the Roman Campagna once for all proved the practicability of living in a highly malarial place during the malarial season, without quinine prophylaxis, so long as there is reliable protection from the attacks of mosquitoes. These three doctors lived in the Roman Campagna (a notoriously malarious locality) for months, moved about outside during the day. but returned to their mosquito-proof house every evening by sundown without acquiring malaria—see p. 41.

Many authorities believe that the mosquito-proof bungalows on the Panama Canal Zone are the most efficient prophylactic measure adopted there. These bungalows are simple in construction, inexpensive, comfortable, and it would appear quite efficacious against the attacks of mosquitoes at night. The Panama Canal Zone was certainly one of the most malarious in the world. It was quite as malarious as the West Coast. The methods adopted by the United States in this zone is probably one of the most perfect examples of applied hygiene in the history of medicine.

(*b*) PERSONAL PROTECTION.

(*i*) *Protection by Mosquito Netting.*

Some form of gauze material around beds to protect from mosquitoes has been in use for many centuries. ANNESLEY as early as 1828 in this country recommended the use of mosquito nets as a protectiou against malaria. They were used to avoid the nuisance caused by mosquitoes for many years before we knew that anophelines were malaria-carriers. In early times in India mosquito curtains for beds were recommended to exclude the "miasmata" giving rise to malaria, or to prevent "chills" from the night dew.

There is no doubt that when properly arranged and used the mosquito net protects from the attacks of mosquitoes at the time when such protection is most needed—at night when asleep. Probably nine-tenths of malarial infections occur at night. The most important point to see to is that the net is free from perforations. Nets should not be touched by the sleeper during the night as he may then be bitten in the part in contact with the net.

Mosquito nets should be hung inside the poles, thoroughly tucked under the mattress (not hanging on the floor), and they should be stretched tight. This last precaution is necessary as a loosely hung, sagging net checks the perflation of air through it and the air inside becomes oppressively close.

The mesh of the mosquito net should not be coarse, as mosquitoes, especially anophelines, are expert in wriggling themselves through a large mesh. When a punkah is required, the frame supporting the net should be very low. The net should always be in a state of repair. The female anopheline will fly around a net for hours in search of an entrance, and she usually succeeds in finding the smallest perforation.

Disadvantages of the mosquito net.—The disadvantages of the Indian mosquito net are the possibility of its not remaining in position; in the case of a long man the foot may be stuck out, or the arm may be thrust out during the night; or unseen perforations may give access to mosquitoes. One great disadvantage of all netting is that the air within gets close and stagnant, rendering sleep in the hot weather difficult. Gauze stuffs generally are somewhat delicate, apt to tear, get foul, and have to be washed, and in India often return from the dhobie riddled with holes.

The mosquito net is indispensable for travellers, and for sportsmen going into the jungle on shooting excursions in malarious regions. Neglect of its use during the malarial season is always dangerous. In houses not provided with wire-gauze doors and windows, it is a *sine qua non*.

Certain Japanese experiments in Formosa gave striking evidence of the usefulness of mechanical protection from mosquitoes and of the power of mosquitoes to convey malaria. A battalion of troops were protected from mosquitoes for 161 days during the malarial season, and all completely escaped malarial fever; whilst 259 cases of malarial fever occurred in an unprotected battalion in the same place and during the same period of time. In another series of experiments on mechanical protection, all windows and houses were gauze protected; further, the sentries at night wore gloves and veils. The following tabular statement will best show the results of the latter observations:—

		Percentage of fresh attacks.		
Half company* protected	(3 experiments) ...	0	0	0
,, ,, unprotected	(do.) ...	338	94	386
Three companies ,,	(do.) ...	443	120	230

(ii) Use of Punkahs and Electric Fans.

Punkahs and electric fans are useful in keeping off mosquitoes during the working hours on the plains, and advantage should be taken of their use by all persons able to afford them during the anopheline season. The electric fan has in many stations in India added considerably to the comfort of living and to the health of Europeans. Punkahs, however, are not reliable protection against the attacks of mosquitoes as these insects may often be found attacking one while punkahs are working. Further, when worked by coolies, the latter frequently go to sleep, and this gives mosquitoes a full opportunity for attack, of which they invariably avail themselves. The punkah coolie is often the person from whom malaria is acquired.

(iii) Mosquito-proof Clothes.

Clothing, if suitable, may to a large extent afford mechanical protection from mosquitoes. The best is woollen material, which not only protects from the bites of mosquitoes, but also prevents chills. Mosquitoes can readily bite through thin cotton clothing.

The dangers of malarial infection are decidedly greater during the evening and at night than during the day, because *Anophelinæ* are chiefly busy in biting at these periods. Mosquitoes are, as a rule, very vivacious in the dusk of the evening, bite through one's socks, attack the hands. face, and all exposed parts of the body.

It is of importance that the feet and ankles should be protected, especially in the evening. The use of boots instead of shoes protects the ankles.

Anti-mosquito veils.—In very malarious places persons moving about in the evening and at night should have their head, arms, feet and legs properly protected from mosquitoes. Men on sentry at night frequently acquire malarial infection. The use of anti-mosquito veils for the face are worn by railway officials of Italy in certain districts. They were likewise distributed in the Japanese Army both in 1904 and 1905 during the Russo-Japanese war. In the latter it consisted of a cylinder of mosquito netting closed at the top, supported by a collapsible framework, all held in position by tapes.

* A half company of Japanese infantry consists of 100 men.

(*iv*) *Culicides.**

Various forms of *culicides* have been in use almost from time immemorial; but we need here only mention those employed in modern times.

Adult mosquitoes may be destroyed by various *fumes*, *gases* and *odours*. Amongst the gases—that of *sulphurous oxide* is the most useful, next comes formaldehyde vapour; of fumes- that of *country tobacco smoke*, smoke of the leaves of the *nim* tree—chrysanthemum powder and pyrethrum powder; and of the odours—menthol, camphor, turpentine, *loban* (benzoin), pastilles, etc.

The fumes of whatever agent is used should be dense, and to effect this every door, window, chimney, and all chinks should be effectually closed in the same way as if one were disinfecting a room by fumigation after occupation by a case of small-pox or other infectious eruptive fever.

Sulphur dioxide.—*Sulphur dioxide* is probably the best direct general fumigant culicide, and in using it for rooms inhabited by mosquitoes, the orthodox method of fumigation by it may be adopted, including the sealing up of rooms, windows, and chimneys. It is, of course, only of temporary service, and does not protect against immigration of mosquitoes into habitations. A few minutes' exposure to air having a high percentage of SO_2 will kill all insects—if very weak in SO_2 it only stupefies them *Sulphur pastilles* are recommended by GILES. These latter can readily be made up by oneself.

One of the best and most convenient ways of using sulphur as a culicide is that of mixing 8 parts of sulphur, 1 part of nitre, and 1 of charcoal, with mucilage of gum acacia,† placing the paste in a conical mould and drying in the sun, a small piece of cotton wick being placed in the centre. A convenient size is 4 ounces, four of which would be sufficient for an ordinary sized room.

GILES in his *Climate and Health in Hot Countries* states that the proportion of nitre (in the formula) is not enough to secure a sufficiently rapid combustion to instantly flood the air with dioxide of sulphur fumes, and that nothing short of a slow burning firework, such as a Roman candle or a Bengal light, will do this in a building roofed with tiles or thatch. Possibly it might be advantageous to raise the percentage of sulphur, and it is undoubtedly better to pack the material as a powder in proper cases than to mould it into pastilles.

Sulphur candles.—Sulphur candles may also be made by mixing sulphur and grease together in moulds, each candle having a wick in the centre. The most convenient forms are those having a diameter of 3 inches and 1 inch in height. These may be placed on a dish suspended in water to prevent fire, as the sulphur in burning splutters a little.

**Culicides* are agents employed to kill adult mosquitoes.

† This is the formula originally suggested by Lieut.-Colonel G. GILES, I.M.S. (R.) in his *Mosquitoes or Gnats*, 2 Ed., p. 221.

It may be stated that there are several kinds of sulphur in Indian bazars, and that some of them are reputed to contain arsenic. All varieties purchasable may, however, be used for this purpose.

It is useless to attempt this by burning a little sulphur in one place and closing the doors and windows. For the sulphur to be useful it is best to mix with it a little kerosine oil and place it on a fairly large protected fire, and make one's exit rapidly. Weak doses of the fumes only stupefy the mosquitoes, they fall to rise again. A proper concentration of sulphur fumes will kill not only mosquitoes, but all other insects with which it comes into contact.

Country tobacco smoke.—Smoking tobacco has long been known as a preventive in the tropics, though the reason for its utility in this respect was not understood, except that the smoke drove away mosquitoes and prevented their attacks.

One of the best ways of ridding a room in which we have to sleep of mosquitoes is to saturate one pound of country tobacco leaf (which can be purchased in every bazar) with kerosine oil in the bottom of a kerosine oil tin and set it on fire—no mosquito survives the effect of the smoke which is evolved, which is almost instantaneous.

Pellitory pastilles.—Pastilles of pellitory root burned in the rooms certainly reduce the number of adult mosquitoes. In the first efforts at destroying adult mosquitoes in Cuba in 1898, pyrethrum powder (from the pellitory root), made into fusible cones, was used. This was found not to be reliable as it only stupefied the mosquito, and did not kill it, which can be readily shown by laying a sheet on the floor of a room in which this so-called culicide is burnt; the mosquitoes falling on to the sheet after a time revive and fly away. Pyrethrum is the chief constituent of many commercial insect powders, and requires eight hours to kill mosquitoes. Fumes from burning quassia wood have also been recommended.

For simply driving mosquitoes out of the house, any fuel burning with a dense smoke, such as moist straw or dead leaves, etc., will suffice. Even a small amount of smoke in a room will agitate resting mosquitoes and put them on the wing to seek means of exit. A denser smoke will narcotise or stupefy them and cause them to fall to the ground. When we wish to drive them out *by smoke only* the *doors* and *windows* must be *left open* during the process, and closed at once when they have made their exit. After they are driven out they must if possible be prevented from returning. On the other hand when we wish to *kill them outright* by poisonous smoke, we should *first close all doors* and windows. In endeavouring to rid a room of mosquitoes in this way, however, it will be necessary to add something to the fire that will poison them; the agent used for this purpose will vary with the resources of the locality and the materials available. In India one of the commonest agents used by natives is ordinary incense, sold in the bazars as *loban* (benzoin), which is made into pastilles. The "mosquito lamp" used in China is said to be a useful method of destroying mosquitoes in a room or within a mosquito net. Dried leaves of wild mint which grows in most parts of this country, has the same effect as quassia fumes. Fresh or dried leaves of *nim* or Margosa (*Azadirachta indica*), where available, may be burnt in the absence of other agents, especially in railway stations. Fumes of quassia wood are less active, killing mosquitoes in five hours. Ordinary wood smoke also causes apparent death in a few minutes, but kills them only after 48 hours unless very dense, a relatively large quantity of the smoke being required to kill mosquitoes outright.

In the case of bamboo huts with thatch roofs, or those raised on piles with perforated bamboo or wooden floors, such as are used in Burma, etc., and which are very porous to smoke, it will be difficult to achieve complete success, but even in such cases thorough fumigation will effect the destruction of the vast majority of mosquitoes inhabiting the hut or house at the time. The best way is to intensify the effects by concentrating the fumes on the mosquitoes suddenly.

Formaldehyde vapour.—This vapour freshly generated from a lamp, rapidly drives mosquitoes from a room or tent. This gas is, of course, a feeble insecticide unless discharged in a fairly concentrated form in large quantities. Formalin vapours have been very largely used and there are many patents of this kind in the market of which some are undoubtedly useful, but it is questionable whether they are preferable to sulphur dioxide vapour.

Camphor and Carbolic Acid.—This combination is largely used in the United States, especially on the seaboard in regions of endemic yellow fever, for the destruction of *Stegomyia calopus*. Equal parts of crystallised carbolic acid and camphor are dissolved by gentle heat, and allowed to act on the room for two hours, 4 ounces of each being used for every 1,000 cubic feet These are put into a small pan suspended over a spirit or petroleum lamp. A white vapour having an agreeable smell is given off. The fumes do not injure anything in the room, and the latter can be at once occupied immediately after use.

It may be stated that culicides alone are unreliable in a large campaign against mosquitoes. They are useful in single houses, in barracks, hospitals, hotels, etc., in exactly the same places where screens are applicable. It is possible, however, in this country to devise some cheap method of using culicidal agents for town houses and village huts, and in a generalised campaign against mosquitoes, this is one of the methods that should be used as an auxiliary to other measures.

One personally has little confidence in the use of fumigants as they are ordinarily employed against anophelines during the anopheline season To be really destructive at this time it should be carried out at night.

Fumigation with culicidal fumes as a general anti-mosquito measure is most useful at the end of the breeding season of mosquitoes, about the middle of spring and before the rains set in. These are the times when hibernating and æstivating anophelines may be destroyed and prevented from giving rise to vast broods during the ensuing breeding season.

(v) *Culicifuges.**

Essential oils.—Various chemical and mechanico-chemical agents have been used to apply to the skin of the face, neck, hands and other exposed parts to keep off mosquitoes. They are usually odorous substances in the form of culicifugal ointments, oil of eucalyptus, oil of rosemary, oil of anise, oil of lemon grass and essential oils generally, kerosine oil and various washes.

The application of the *essential* oils wards off mosquitoes to some extent—one in great favour in some parts of India is *lemon grass oil*, which is pleasant, harmless and procurable from all large chemists in this country, and in many large bazars. It is the oil distilled from several species of Andropogon. The specimens of lemon grass oil met with in India differ somewhat in appearance. The true oil is of a pale shiny colour, transparent, with an extremely pungent taste and a peculiar fragrant lemon-like odour. In bazars it is known as *Akya ghas ka atr*.†

Kerosine oil. – Much as she abhors kerosine oil, the female mosquito will smother her dislike and feed off a surface covered with it, if that surface belongs to a human being. In Manipur, which in the late autumn swarmed with anophelines and culicines, one repeatedly coated one's legs with kerosine oil and left them bare under the table in the evening, and on one occasion watched seven anophelines gorging themselves with blood.

The sprinkling of kerosine oil about the bed-room and tying a towel soaked in the oil to the bed-posts above the head is a very inefficient substitute for mosquito nets.

With all these applications as soon as the volatile part of the oil, essence, or ointment has evaporated, mosquitoes will unhesitatingly begin their attacks. While, therefore, they are effective for the first twenty minutes or half hour, they are of no use afterwards as protectives. One in the meanwhile may fall asleep under a sense of false security, to be assailed by anophelines, and possibly infected, by malaria while asleep. When female mosquitoes are decidedly hungry and in crowds, they will overcome their distaste for all such applications.

One cannot therefore recommend any of the known culicifuges as protective against malaria, and would warn those depending on them that they will sooner or later fall victims to malarial infection.

It is quite possible that in course of time some culicifuge will be found which will prevent mosquitoes biting malarial patients—then

* *Culicifuges* are agents that prevent the bites of mosquitoes.

† WARING'S *Bazar Medicine of India*, 6th Ed., pp. 103, 104.

isolation of both healthy and infected will be an easier matter than it is now. It will then be possible by the application of some protective material on the exposed parts of the body, or the use of substances that drive away mosquitoes, to prevent their attacks.

Cultivation of castor oil and other plants useless.—Some plants are reputed to keep mosquitoes away from houses, but so far none have proved useful in this direction. The castor oil bean plant was considered to act in this way, but it is known that mosquitoes will actually settle and rest under the leaves of this plant.

Occium viride.—It has been stated that the plant known as the *Occium viride* has the virtue of keeping mosquitoes away. The evidence, however, on this property of the plant is very scanty, and, such as it is, unsatisfactory.

It is a mistake to cut down jungle *indiscriminately* in the belief that jungle harbours mosquitoes. This may give anophelines an inlet from infected huts, or from breeding grounds.

Hand-nets for capturing mosquitoes.—Colonel Gorgas (U. S. A.) in his campaign against yellow fever in Cuba, while especially directing his attention to the *Stegomyia calopus*, destroyed all mosquitoes found by hand-nets, made something like ordinary butterfly nets. The destruction of mosquitoes by hand is not to be ignored, and in isolated houses, barracks, hospitals, out-offices, etc., a considerable number of infected mosquitoes may thus be got rid of.

The destruction of adult mosquitoes is at best a very unsatisfactory process and one that cannot in any place be relied on *per se* as an anti-malarial measure, although it may be a useful auxiliary.

Tinctorial prophylaxis of mosquito bites.—The tinctorial prophylaxis of mosquito bites is not without its importance; such colours as navy blue, dark red, reddish brown, and black, are more attractive to mosquitoes than articles of white, slate-grey, green, light yellow, and violet, and it is probable that the white clothes worn by inhabitants of the tropics generally, serve a useful purpose in this direction.

E.—Removal of Breeding Grounds of Mosquitoes and Destruction of Mosquito Larvæ.

Drainage and Regulation of Surface Waters as Anti-mosquito measures.

Drainage on a large scale.—One of the main prophylactic measures for the reduction of malaria is drainage, which acts by doing away with the breeding places of anophelines. On a large scale drainage is called for wherever the subsoil water level is high or the soil water-logged (even temporarily), and where there are marshes or other large collections of water acting as breeding grounds for anophelines. Drainage as part of public prophylaxis against malaria has, we know, been practised for many centuries. In a *Report of the Italian Society for the Study of Malaria* for 1906, the opinion is recorded that "improvement in drainage should first be undertaken in a malarious locality ; then improvement in agricultural methods, *i.e.*, regular and careful cultivation ; then should follow the new anti-paludal measures." This may apply to certain limited districts, but it is doubtful whether many medical officers of Indian experience would advise the application of such an important generalisation to our larger endemic malarial districts in India. From a scientific point of view, it is possible theoretically, with great expense and labour, to drain towns and cantonments in this country in such a way that malarial fevers would be considerably reduced. It is, as far as one can judge, impossible, theoretically or otherwise, to do so in our large agricultural districts in India and Burma—this is especially so in rice-growing districts.

Free drainage is the most direct means of counteracting the influence of malaria ; and as this is naturally attained more particularly in isolated mountain elevations, such situations are usually free from fever, although these maladies are not uncommon in warm mountain valleys, thus showing that to some extent at least it is only in proportion as mountains are better drained than the plains that they are more free from breeding grounds of anophelines. We know that the Himalayan Terai is one of the most malarious tracts in India.

All the larger works of drainage, canal-making, irrigation, etc., must necessarily be controlled and inaugurated by Government. One is convinced that Government would be ready and willing to spend money on sanitary measures that could be definitely shown to be prophylactic against malarial fevers in communities. It is not easy for the sanitary officer in particular cases to state emphatically that the measures he recommends will unequivocally eliminate, or even mitigate, malaria. He can only base his opinion on the principles already stated, and illustrate the advantages obtained in certain districts in which anti-malarial measures have been systematically carried out on a large scale. Drainage on a large scale is always a serious undertaking ; even in small areas, drainage scientifically carried out, means expenditure of funds which at first sight appear disproportionately high to the prospective results.

The question whether there should be greater State intervention in connection with hydraulic sanitation as an anti-malarial measure throughout this country is a problem which one does not here attempt to consider. It would appear that there are some districts in which such intervention could be profitably undertaken, and the areas rendered less malarious. Even in cases where the conditions are favourable to this it would necessarily be a work of slow progress.

The drainage of the area in and around the European Troops' barracks in the Island of St. Lucia is one of the few instances in which a clear case of the effects of drainage alone, by reducing the number of anophelines. brought about a considerable decrease in the admission-rate for malaria. The whole work occupied four years and the full effects were not manifested until towards the end of the fourth year. This instance is one uncomplicated with other prophylactic measures. The barracks were not mosquito-proofed with wire-gauze, mosquito curtains were not used, and quinine was not given prophylactically. Reliance was entirely placed on clearing, drainage and general sanitation against mosquitoes. A severe epidemic of malarial fevers led to drainage works, etc., with a view to exterminating mosquitoes ; this was followed by a great diminution of malarial fevers.*

Another instance is that of the Island of Samarai (Papua), in which it is stated anophelines have been entirely exterminated by the drainage of one large swamp. There are stations and cantonments in India in which the drainage or filling up of half a dozen tanks and various borrow-pits would greatly reduce the malaria.

Large drainage schemes nearly always take some time to show any distinct influence for the better, and usually it is not until well into the second year that the number of admissions of malarial fevers is much decreased, and this diminution continues, and is more marked, by the end of the third and fourth years. In really comprehensive drainage works that take several years to carry out, it frequently happens that it is not until the work is approaching completion that malarial fevers are materially lessened.

Well-devised efforts of drainage, intelligently directed and persistently carried out, would eventually succeed in greatly reducing the malarial incidence of many towns and stations in India.

The salutary effects as regards malaria following drainage of a previously malarial district is not entirely due to the drainage, for it is well known that drainage *per se* is an anti-malarial measure that takes a long time to operate beneficially. There are other factors such as improved sanitation, water-supply, better housing, healthier lives, general levelling of the surface, impermeable roads, abolition of collections of water that previously existed, and all the other attributes of industrial prosperity, that must be taken into account before we can estimate the intrinsic merits and influence of drainage alone.

Whatever form of hydraulic sanitation is instituted in any particular locality must be undertaken in view of the present known epidemiological facts connected with malaria. "The essential requirement of all systems of hydraulic sanitation is that they do not leave a way for the larvæ and nymphs of anophelines to live in the water." (CELLI.)

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* Lt.-Col. F. P. NICHOLS, R.A.M.C., "*Effects of Large Drainage Works on Malaria*," *Journal of the Royal Army Medical Corps*, April, 1907.

We should not forget that there are instances in the history of malaria in various countries in which the initial stages of the drainage of marshes and malarial districts have been associated with outbursts of malaria of a virulent type. Such was the case in some of the drainage operations in England during the early part of last century, in certain parts of Italy between the Tiber and Arno rivers, and the terrible record of the drainage of the marshes near Chartreuse in 1805.

The drainage schemes of towns, villages, cantonments, collection of houses and huts, should be planned during the rains, as at this time it is easy to see where water collects, and roughly the amount of storm-water that has to be provided for.

The various applications of drainage on a large and a small scale in connection with anti-malarial sanitation are referred to in the following pages.

Regulation of surface waters.—The chief surface waters here referred to are rivers, streams, irrigation canals, lakes, marshes, and natural and artificial collections of water of all kinds. These may be regulated so as to prevent inundation, effect their drying up, or by putting in motion stagnant or nearly stagnant water. Anophelines specially favour still or nearly still water.

There are various systems of dealing with large surface waters open to sanitary and irrigation engineers. We will here deal with a few of the more important.

Regulation of rivers and streams.—This is an important factor in all general systems of prophylaxis of malaria in India. One of the most important measures is preventing inundations, which in endemic malarious districts give rise to the production of marshes and pools, and so to an enormous extent favour the occurrence of malaria.

Methods of preventing inundations of rivers.—Amongst these methods one would refer to—vegetation on mountains and their slopes; steps; parapets and traverses; repellents; rectifications and deviations; settling or retaining basins; deviations and locks; embankments; works of defence against washing away of bed; systematisation of the mouths, *i.e.*, weirs or locks, or dykes in the sea.

Woods on the slopes of the mountains.—These retain a certain proportion of the rainfall and yield it to streams by slow degrees. Disforested mountains at every heavy fall of rain permit of torrents descending from the slopes which may cause excessive inundations of the plains.

Steps.—*Steps* on the slopes of mountains and hills materially lessen the velocity of the fall of water, and when the slope is very precipitous, their construction is one of the few ways in which overflow of streams below can be prevented.

Traverses.—In the case of *torrential streams* and *rivulets*, by placing obstructions of various kinds in their course, the force of the flow is much lessened. *Traverses* have been used for this purpose for centuries. They are usually in the form of trunks of trees and their branches, large stones or any other available form of obstruction. They lessen the force of the current and reduce the amount of débris carried down. *Repellents or dams* operate in a similar way.

Embankments.—To prevent inundations of rivers *embankments* are sometimes constructed, but even these may be overtopped and the whole of the neighbouring country more or less submerged. There are in India a large number of small rivers and streams near towns and cantonments that overflow their banks every year and leave anopheline breeding places which last throughout the malarial season and then dry up. In the majority of these a certain amount of embanking would remove this very widespread source of breeding grounds. One could refer to several stations where complete canalisation of streams would effectually remove all breeding grounds. The same holds good, with some modifications, in regard to the larger rivers, such as the Ganges, Jumna, Beas, and Ravee, which after overflowing, leave extensive breeding places.

Settling basins and locks.—These are used during flood times; they operate by allowing the water to flow into reservoirs in such a way that the overflow of the banks of the river is prevented. (Celli.)

Paving of bed of rivers.—*Paving* as a means of defending the bed of the river from being washed away has been carried out in a few places successfully. It is carried out in some of the larger irrigation canal works in this country, and it is a method applicable to a large number of streams that dry up during the hot weather, but which form large pools during and after the rains.

The methods of preventing the inundations of rivers are dealt with in works on engineering, and have an important bearing on the epidemiology of Indian malaria.

In the case of small streams the task usually resolves itself into renovating the bed and banks so as to remove the possibility of pools forming. In rivers, also, the banks should be seen to, so that side pools cannot arise.

It may be here remarked that it is not possible to keep up an exact and uniform gradient in an unrivetted water-course, and that the kutcha water channels of most of our Indian stations, by favouring the formation of pools, create many breeding places for anophelines.

Rough canalisation of rivers, streams, etc.—Attention should be given to the beds of rivers, streams and discharge canals. This may appear at first sight an enormous undertaking in connection with such rivers as the Ganges and Jumna. In reality it is not so, and mosquito gangs are practically in all cases sufficient to carry out the work. This consists chiefly of rough canalisation of pools that are left by the contracting river after the monsoons, filling up small hollows, brushing larvæ over on to the sands, keeping any larger pools which cannot be drained free of grass and weeds, and the latter from the main channel of the river itself—all within half a mile above and below the town or cantonments we are operating on. One is quite confident that such measures carried out in connection with Indian rivers near towns, stations, and cantonments would reduce the anopheline population in those places. In the case of all larger rivers the work has to be continuous from the time they commence contracting until the flood time of the ensuing year. The number of men required will rapidly lessen as the river dwindles until a few are capable of doing all that is necessary. After heavy rains the work will often be laborious. Were the beds of our Indian rivers properly canalised, embanked, and kept within definite limits in towns and cantonments as they are in Europe, all this would be unnecessary.

By *rough canalisation* one means the collecting of the stones or mud on each side of streams, ditches and water channels generally, so as to confine the water channels within the two sides of a limited surface, or deepening the beds here and there when necessary, in order to remove marginal pools and to give a straight and constant flow of water. Such work should be commenced each year at the end of the rainy season in order to remove the stagnant pools which might breed mosquitoes. Work of this kind in the lower parts of the streams may of course be carried away during flood times. Rough canalisation of rivers and water-courses generally has a wide application in the removal of breeding places of anophelines in this country. It is work that can be readily carried out if the right class of men, *malis* and agricultural labourers, are employed.

Ditches.—" It is often feasible to regulate all the ditches of a locality by embanking and deepening them, or better by carrying away their perennial rain water in drains, and adapting the ditches for the reception of storm water. If these ditches were paved, at least in some parts, the work would be more lasting and certainly very generally much more useful.—(CELLI.) "

Another method may be employed where *springs at the foot of hills* give rise to marshes and maintain a high ground water level. Rain-water collecting between the soil and the underlying earth descends towards bottom of hills, and increases the size of springs, which, collecting in hollows, form marshes. For these a circular trench is made round the base of the hills which intercepts the water. Other trenches then carry the water into larger ones, until they finally discharge into a stream or a river. When there are a number of springs it is advisable to endeavour to connect them and form one large spring, otherwise they form several small pools of water which are specially prized by anophelines as breeding places. The rate of flow in bodies of moving water has an important influence on the breeding of mosquitoes. CELLI has shown that a velocity of 63 mm. per second is compatible with the presence of larvæ of anophelines.

Anophelines will be found to breed especially in sluggish running streamlets or rain-water runnels, in stagnant terrestrial waters, amongst weeds and grass, in pits or holes in the ground, hollows in rocks, in ponds, cisterns, and not in rapidly running rivers and streams.

Banking of lakes.—*Lakes* with shallow pools around may be *deepened* and *banked*, and the banks kept clear of grass and weed.

Marshes, swamps, jheels.—The questiou of the best way of dealing with marshes and places simulating marshes by anti-malarial measures is probably one of the most formidable we have to encounter—it is never easy; it is usually a serious undertaking. There are various ways in which we can approach the subject of marshes with the view to lessening their evils or doing away with them.

The easiest method, when practicable, is that of cutting discharging canals which have a sufficieut fall into some water-course or depressiou. This is one of the most important and most economical ways of dealing with them. In the case of the Agro Romano the latter was divided into basins and the proprietors of the land united together to open canals for the discharge of the stagnant water. One of the difficulties in connection with such canals is their maintenance in proper condition, and the removal of vegetation which, from marsh lauds, is very luxuriant and so blocks them. The silting up also leads to obstruction, especially when there is not a good fall.

In many marshes a small amount of drainage work iu the shape of setting free different collections of water by cuttiugs (which can be made by half a dozen men) all round, and in different directions, are often most useful in decreasing the breeding area for mosquitoes. It may be possible to drain even large collections iu this way into the natural direction of the flow, or smaller collections may be drained into larger oues. It is also possible to fill iu many of the irregularities with earth, and so again lessen the area of the water surface.

Circumvallatory drains.—In the case of large marshes the *intercepting* or *circumvallatory drains* are preferable to cutting channels through or across them—the are cheaper and more effective.

Covering marshes with alluvium.—This fundamentally consists of covering lowland with mould. A river near at hand is allowed to flow over malarious land, and there deposits a considerable amount of mud, and thus by utilising periods of flood, an area is gradually covered with a stratum of rich mould which has beeu washed down from higher land. This ingenious method has reclaimed various malarious marshes in

Italy, and is to some extent applicable to certain districts in India, such parts of the valley of the Indus, Ganges, Brahmaputra, etc. This system of natural covering has been extensively employed. It takes long, sometimes centuries, but the results are positive and satisfactory. While this natural covering process is going on, the injurious effects it produces have been, and are, complained of. A typical instance in which this method is applicable is the Bela land below the Fort and Daryaganj Cantonment in Delhi, but it would take many years to accomplish, and in the meanwhile malaria would be continuous.

Absorbing wells.—In some places *absorbing wells* have been sunk to receive and drain underground water. These are specially useful in places where the underground stratum consists of gravel, pebbles, etc., which allows of percolation. When the impermeable stratum is bored in many points, the level of the underground water is lowered considerably, because a great part of it disappears in the underlying earth.

Machine pumps.—For marshes in the form of morasses and bogs, *machine pumps* have been used to exhaust, or put in motion, subsoil waters that have no natural outlet.

Artificial covering with earth is of limited application and useful only in small marshes, for excavations in the form of borrow-pits, and all small hollows and irregularities of the surface howsoever created.

Rubble drains.—These are useful in lowering the level of the subsoil water. A channel of requisite depth cut through or around a marsh, is filled with stones—large stones at the bottom, smaller ones on top. These are identical in principle to the subsoil drains used in certain parts of Ireland and other countries of Europe. When water percolates through the interstices of the stones, it carries away silt automatically and prevents the growth of grass and weeds. In certain localities these form excellent drains. Broken stones, clinker, and pebbles, are very useful for this purpose. In the Roman Campagna tufa in large blocks is used. These blocks are placed one along each side and another on the top so as to enclose a triangular space in the trench, which acts as a drain. Large pebbles may also be thrown into the bottom of the drain so formed (CELLI).

By such a system of drainage, or some modification of it, extensive areas may be successfully kept dry; indeed there are vast tracts in the English Fens, in France, and Germany that have been rendered healthy and non-malarious in this way. Such a system of subsoil drainage is largely applicable in certain towns, stations and districts in India, where there is a high subsoil water level.

Drainage by exhaustion.—"Extensive works have been carried out during late years for the drainage of large marshes in Italy such as those of Ostia and Maccarese. For this *hydrovorous machines* were used. The idea of this drainage, which is also called *drainage by exhaustion*, is very simple and ingenious. It is employed for marshes whose bottom is in some parts below the level of the sea, consequently it is not possible to cut ordinary discharging canals, there being absolutely no fall for the water."

These machines raise the water which is at a low level, and discharge it into the water at a higher level; both are then conducted to the sea by means of an ancient emissarium which formerly only conveyed the high water of the basin to the sea. The water from the periphery, which, in its turn would go to the bottom of the basin, is kept back and carried away by canals, which thus separate the high water from the low. Both waters re-unite at the emissarium, which conveys them to the sea. From the hygienic point of view such work has not up to the present been of much advantage. The filling up of deep lying ditches and basins (It. *colmata*, from Fr. *kolmätage*) was practised as sanitary improvements for reclamation of the land. "These were seldom carried out directly for the sake of husbandry, but usually by permitting an inflow of water from the next stream or the sea, which is allowed to sedimentate, the process being repeated until the required level was reached." * Such improvements take many years in their achievement. The largest works of this kind have been carried out in Italy. MARSH writes: -"The success with which human guidance has made the operations of nature herself available for the restorations of her disturbed harmonies in the Valdi Chiama and the Tuscan Maremma is among the noblest, if not the most brilliant, achievements of modern engineering, and regarded in all its bearings, it is, as an example, of more importance to the general interests of humanity than the proudest work of internal improvement that mechanical means have yet constructed. The operations in the Valdi Chiama have consisted chiefly in so regulating the flow of the surface waters into and through it, as to compel them to deposit their sedimentary matter at the will of the engineers, and thereby to raise grounds rendered insalubrious and unfit for agricultural use by stagnating water; the improvements in the Maremma have embraced both this method of elevating the level of the soil, and the prevention of the mixture of salt water with fresh in the coast marshes and shallow bays, which is a very active cause of the development of malarious influences."

Submersion.—It is a curious but well-known fact that whilst marshes are completely submerged, they may be non-malarious. Instances of marshy places known to be excessively malarious having become more or less suddenly healthy are very common, the only change occurring being that the marsh has become flooded with water, either naturally or artificially. If a stratum of water is made to cover a

* NOTHANGEL's *Encyclopædia of Medicine*, Vol. on *Malarial Diseases*, p. 485. Edited by RONALD ROSS and J. W. W. STEPHENS.

malarious site so long as the water remains at a constant level, there will be brought about a relative improvement. Submersion, however, is only comparatively beneficial. When other methods are economically feasible submersion is to be avoided. The conversion of a malarious tract, such as a swamp, into a lake, is a sort of paradox in the light of our present day views of malaria. The natural covering by utilising the inundations of rivers is a real natural sanitary measure which eventually leads to a raising of the soil level sufficiently to prevent the formation of marshes.

If the basin to be filled up is large and the river water only a little muddy, the improvement takes place very slowly, but its effects are certain and definite. There are many instances of this having been carried out in Italy. In Ostia and Maccarese this covering was very successful, because the Tiber which flows between them is very muddy, and carries down a large amount of material which deposits.

Regulation of irrigation waters.—No system of irrigation is complete unless there are adequate arrangements for the discharge of the effluent. In many instances this matter is left unthought of. Once the water can be made to flow over the fields, whether in wet cultivation or dry, the effluent is left to make its own way out. This is almost the invariable rule in the irrigation carried on from wells by ryots and from many irrigation tanks. The result is that there is always a certain degree of saturation of the soil, and if there be no natural water channel, or if a layer of impermeable clay be a short distance below the surface, a common condition in India, a soil saturated with water is the result. This is one of the great causes of the prevalence of fevers in agricultural villages and outskirts of towns where rice is the main crop, for such villages are always adjacent to the fields themselves, and the surface soil of the village is kept more or less constantly moist, with the result that the existence of breeding pools for anophelines is universal. All this could be obviated by proper preparation of the fields for the reception and subsequent discharge of the water into prepared channels. The same condition arises wherever the level of the subsoil water is raised from any cause. In some irrigated areas there are waste effluents, but there are extensive tracts in which no such effluents exist. It has been suggested that if the water from irrigation channels can be kept flowing at a certain rate over the fields, mosquitoes would be prevented from breeding in them. Whether this would act efficiently or not could be readily put to the test in irrigated rice and sugar-cane fields.

Whenever any irrigation works are carried out, or any works which will increase the amount of water in the soil, it is necessary to simultaneously carry out adequate subsoil water drainage to remove the effluent. Neglect of this in India will invariably be associated with increased malarial endemicity in all newly-irrigated districts.

The subsoil water level may be raised by various circumstances, amongst these—rain; drainage from surrounding country, adjacent or remote; blocking up of the outlets of water-courses; and pressure from water in adjacent lakes, tanks, or rivers, especially if these are above the level of the locality under consideration; overflow of the banks of rivers, etc. The method of lowering to be adopted will, naturally, depend upon the cause which has raised the level of the subsoil water.

The existence of irrigation in the Lahore Cantonment was supposed to be the cause of failure of the anti-malarial measures carried out by S. P. JAMES and CHRISTOPHERS in the years 1902—06 JAMES and CHRISTOPHERS have described the results of the anti-malarial operations at Mian Mir, which were carried out persistently for two years. The result was a failure to make any material impression on the malarial intensity among the troops of that cantonment. Every effort was made to destroy larvæ in the irrigation canals in a section of the cantonment to a large extent isolated from the rest. The authors attribute the want of success, not so much to the fact that larvæ were not destroyed, for they were in myriads, but to the fact that "anophelines filtered into the cantonment from villages a mile or two away." This was an unexpected event, and contrary to all previous knowledge of the flight of mosquitoes. Among their conclusions are:—That "(1) it is easy enough to destroy larvæ in millions, and to do away with hundreds of breeding places, but it by no means follows that malaria is diminished or adult anophelines banished, and the success of operations on a large scale is still very doubtful; (2) the idea that by destroying breeding places around a barrack, prison, or other building, a reduction in malaria is likely to result, requires more critical study before it can be accepted; (3) the occasionally reported cases where a mosquito brigade has rid a town of malaria, we have no hesitation in challenging as absurd."

Storage irrigation tanks.—These can be cemented or lined from edge to bottom with large stones embedded roughly in earth. This is a form of work at which mosquito brigade gangs are experts. Tanks of this kind are dispersed all over rural India, especially in the Deccan. When neglected, allowed to collect water weeds, long grass, and reeds, they are veritable nurseries for anophelines. On a small scale cisterns for storing irrigation water are used in public and private gardens; these should be made pucca and covered to prevent the access of mosquitoes.

All engineering and other works which tend to raise the subsoil water level in a locality, which has all the factors for engendering malaria in it, are likely to convert such a place into a highly malarious one.* This remark holds good regarding railway embankments, all large building undertakings, barracks, industrial workshops and factories, extension of towns, erection of villages, etc. In the construction of railway lines engineers should specially avoid interfering with the natural drainage of the subsoil.

* This subject has been dealt with in PART I, EPIDEMIOLOGY, p. 33 *et seq.*

Any neglect in connection with the filling up of excavations, borrow-pits, is dangerous—these should at least be drained before being finally quitted by workmen.

With the view to decreasing borrow-pits as a source of anophelines, it has been suggested that material for road-making be taken about 20 feet from the edge of the proposed roadway which gives a wide berm. Draining of borrow-pits is said to be objectionable from an engineering point of view as running water tends to scour out the foundations of the roads. There is but little to support such a view. The object of such drainage is to do away with borrow-pits and their consequent collections of stagnant water; it has nothing to do with the general drainage of the neighbouring country. With such drains the borrow-pits would dry up and cease to be what they are now, nurseries for mosquitoes. A small, properly graded drain along the side of roads is sufficient for the drainage of the road itself. The remedy for roadside borrow-pits appears to be in the construction of graded katcha drains in all the borrow-pits now in existence at the sides of roads. These should have an oval bottom and be about one foot in diameter and nine inches deep. Such a system would remove the present risks. It would be more economical than grading the whole of the borrow-pits and cheaper in the up-keep.

Attention to water channels.—Water channels require regular clearing of grass and weeds and when *katcha*, regular grading and levelling. The best laid drain, in places where the fall is small, will, after a few months, if not kept clear of silt, grass, and weeds regularly, become choked with sediment and vegetation. A simple clearing during the anopheline season is not sufficient; it should be carried out every fortnight or at least once a month, the more frequently the less labour each time.

Tanks.—A large number of tanks and excavations form, as it were, centres of gravity for all surface waters falling in their vicinity; rain-water runnels may be seen fissuring various parts of their perimeter. To obviate this until such tanks can be filled up, *katcha* intercepting drains, as shallow as is consistent with efficiency, should be dug round them and the water conveyed in the direction of the natural fall of the land; or, if at hand, into artificial drains. In towns and cantonments when tanks are about to be filled in, some arrangement should be made in connection with these *katcha* intercepting drains to allow refuse carts (when dry refuse is being used for filling) to reach the tanks—old spare iron pipes placed at the bottom and covered with earth will answer the purpose. When the tank is itself filled up, the intercepting drains should also be abolished before the work is finally quitted. A number of tanks and borrow-pits have shallow and deeper parts; where the work of complete filling up cannot be carried out, the shallower parts should be filled up. This would give a smaller area of water surface for anophelines to breed in, the deeper parts being taken in hand when funds for the purpose can be spared. Deep waters are not favoured by anophelines.

Dry refuse for filling tanks and borrow-pits.—There are many small and large tanks, and collections of surface water generally, forming breeding places of anophelines in and around towns, stations and cantonments, that could, without risk to health, be filled up with dry refuse. This should not be done, however, when such excavations are within 100 yards of villages and within 200 yards of bungalows and barracks. Stable refuse will form breeding places for flies unless special care be taken to render it uninhabitable to maggots. The best way to do this is to keep the refuse dry. In all cases the final levelling should be carried out with a layer of earth several inches deep. When filling up large excavations with dry refuse is decided upon, the work should be carried out systematically, beginning during the cold weather, and, where possible, completing the work before the onset of the ensuing rainy season. If the capacity of the excavation is too large to complete the filling and levelling before the rains, it should be divided up into sections by one or more katcha *bands* or mud walls, and each section taken in turn, the object being to prevent decomposition and fermentation through admixture with water. The earth for these *bands* may, if there is no rising ground in the neighbourhood, be taken from the margin of the excavation.

The shallower parts of tanks and excavations that retain water should always be taken in hand first—the deeper parts should be taken up finally, each part being finished before the next is started and before the rains begin. If the deeper parts contain water it should be baled out before the filling is begun. A large number of tanks could in this way be filled up and levelled at a comparatively small cost, and in places where there is little or no earth and draining is impossible, this is the only way available without inordinate cost.

The length of time it takes to fill tanks and borrow-pits generally with day refuse is readily calculated by ascertaining their capacity together with that of the amount of dry refuse available daily.

A large number of tanks and excavations are fairly deep in some parts, especially near the middle, and shallow towards the banks. The shallow parts retain water for a few months after the rains and gradually dry up. These shallow parts, especially when pools are left in them, are much favoured by mosquitoes for laying eggs in. In these cases when the process of filling up the tank cannot be carried out at once, it may be taken in hand by stages. If the bed of the shallower parts were raised a foot or so and properly levelled, these parts would cease to hold water. The bed of the deeper parts may then, when funds are available, be raised to the level of the shallower parts.

Most tanks that are uniformly deep are not used as breeding places by anophelines, and it is necessary to state that if such tanks are only partially filled up, by being made shallower, they may be converted into nurseries for anophelines. Hence deep tanks, unless known to breed anophelines, may in a large number of instances be allowed to remain, the banks being made abrupt and the edges kept free from grass and weeds.

Lowering the level of the general surface for filling excavations.—In many instances excavations may be filled up by lowering the general level of the surrounding area for several inches. In a large number of places on the plains the soil is a sandy alluvium and moderately porous, so that a superficial reduction of the level is not likely to allow water to collect long enough to permit *ova* of anophelines breeding into imagines. Where this is done, however, strict supervision is necessary to ensure that such lowering is quite uniform and that no pits or irregularities of the surface are created. Before the work is finally quitted it should be seen that the whole of the surface of the newly-created depressions is quite level.

The filling up of tanks and borrow-pits is one of the most important anti-mosquito measures required in and around Indian towns, villages, and cantonments. Such excavations are one of the most fertile sources of mosquitoes in this country. In some instances where there are a number of borrow-pits, some small and shallow, others large and deep, adjacent to one another, the smaller might be drained into the larger, or the smaller ones filled up from the larger ones, and the latter treated as isolated breeding grounds—the banks being made abrupt and the edges kept free from aquatic vegetation.

Creating borrow-pits to be strictly interdicted.—It is urgently necessary that the excavation of earth for building or other work should be rigidly prevented within a thousand yards of towns, villages and cantonments. The construction of houses should not be considered complete until every excavation created has been filled up and properly levelled. The earth required for such buildings should not be excavated within 1,000 yards from towns, etc. Slight depressions of the general surface, irregularities in surface drains, and shallow pits and hollows which lodge water only for a short time after the rains, should all be abolished as they serve as breeding places for at least one or two generations of anophelines. It is important that these early generations be prevented as the thousands they give rise to at the beginning, become hundreds of millions during the latter part of the breeding season.

Garden cisterns.—Where the beds of the gardens are fed by drains from well cisterns, these drains should be pucka; all waste drains from gardens should also be pucka and empty into the branch and sub-main drain. The puddles formed by the waste waters from gardens are a prolific source of malaria-bearing anophelines. When this cannot be carried ont, then either the cisterns should be covered with mosquito-proof material, or the cisterns should be completely emptied once a week during the mosquito season, and where the supply of water is limited and does not permit of this, the surface of the water should be treated with a mixture of equal parts of pesterine and kerosine oil on two consecutive days weekly during the malarious season.

Other domestic water containers and all domestic supplies of water, such as those in chatties, kerosine oil tins, etc., should be provided with mosquito-proof covers. or emptied at least once a week and kept empty for several hours during the daytime. All buckets for water in case of fire accidents should be emptied once a week or treated in the same way with kerosine oil and pesterine. In refilling these water containers it should be seen that mosquito larvæ are not introduced with the fresh supply of water. One has on three different occasions found the larvæ of *Nys. stephensi* in chatties.

Disused wells.—Many unoccupied bungalows have wells out of use. These sometimes swarm with culicines, and occasionally in them *Nys. stephensi* breeds prolifically. A pail of water thrown around the lining of the well may succeed in driving out some of the adults who are usually resting on the wells. All such walls should be provided with mosquito-proof covers. All permanently disused wells should be covered with some solid material such as reinforced concrete. Wells that are in constant use do not breed mosquitoes.

Brick Factories.—In a number of towns and cantonments there are brick factories either within municipal or cantonment limits, or just outside these limits, the borrow-pits of which form breeding places for anophelines during, and for a few months after, the rainy season. No brick factory should exist within 1,000 yards of municipal or cantonment limits, and in selecting sites for brick-kilns, even at this distance, the possibility of future extension of these limits in the direction of the site chosen should be borne in mind. The building of houses and huts with pucka bricks made in selected sites, instead of sun-burnt ones made on the spot, would to a large extent do away with the creation of tanks.

Grass Farms.—No land within 400 yards of municipal or cantonment limits should be used for grass farms, when, within 100 yards of the grass land, there are collections of water known to be breeding grounds of anophelines. The grass in the latter case, even when half-grown, affords rest and shelter to anophelines passing from these breeding grounds to feed on man, and again when returning to lay their eggs. Grass farms, as such, have no connection with malaria, but when the grass land is near both breeding places and inhabited localities, it favours anophelines and through them malaria is disseminated.

Thatch roofs.—Thatch should not be used for roofs of houses. They harbour anophelines during the malarious season, and in many cases also serve as places in which they may either hibernate or æstivate during non-breeding seasons. Tiles are decidedly preferable. It is well known that mosquitoes during the rainy season are much more numerous in thatch houses than tiled ones.

CULTIVATION AND ARBORICULTURE AS ANTI-MOSQUITO MEASURES.

Cultivation of the soil.—Until the discovery of the malaria-mosquito relationship, there was, apart from the use of quinine, practically only one method of general prophylaxis of malaria in operation in rural districts amongst civilised nations, that of *cultivation* of the soil in which was included the *regulation of the level of the ground water*. The latter has already been alluded to in pp. 186—200. Drainage and cultivation are specially applicable to areas where these can be carried out profitably. Complete and permanent drainage of malarious land, that will not repay the cost of draining and cultivating, cannot be recommended.

In a general way it would appear that the existence of proper cultivation of the ground and malaria have from the earliest times been antagonistic to one another; in regions where cultivation has been neglected malaria has prevailed, and when husbandry has been systematically carried out in malarious places, there malarial diseases greatly decreased or completely disappeared.

In general terms it may be stated that all the more approved methods that have been employed on a large scale, and that have stood the test of time, have had the common object of regulating the level of the ground water in such a way as to enhance the fertility of the soil.

"History teaches that if man has frequently sacrificed himself for the redemption of unhealthy places, it is nevertheless true that unhealthy lands can only be cultivated at the risk of the life of the workmen and the substance of the owner." (CELLI.)

Levelling and ploug ng.—*Levelling* and *ploughing*, etc., of land under cultivation have some effect in reducing malaria by making the soil more permeable to water and preventing the formation of pools.

Intensive cultivation.—*Intensive cultivation*, which is best represented by the rapid rotation of crops in market gardens, has rendered many areas less malarious and in some cases quite eradicated malaria. It is also the most profitable where it can be brought into operation. Land which has been under cultivation, when long neglected, becomes a focus of endemic malaria. This is the origin of part of the malaria in this country. The same happens after extensive clearing of forests when the land is not put under cultivation. The clearing of forests is said to be responsible for the increase of malaria in certain parts of Mauritius.

Arboriculture as an anti-mosquito measure.—With a view to drying the subsoil, trees have been planted on account of the great activity of the transpiratory function shown by growing vegetation and the consequent absorption of excessive moisture from the soil, the number of trees planted being in proportion to the needs and dimensions of the locality. This application to a scientific principle has, however, little application in this country, but when employed is best adapted to soils having no natural subsoil drainage, as usually is the case in flat, low-lying and marshy districts.

Well-regulated cultivation of the soil is always healthy, but the beneficial influences following the planting of trees have been extolled beyond their intrinsic merits, and the probability is that such improvements as have occurred are to some extent also due to simultaneous levelling of the soil rather than to the drying effect, rapid growth and the speedy evaporation from trees. In this country such plantations can only be carried out on a comparatively small scale, and can never be successfully applied to the larger districts of endemic malaria.

Special plants and belts of trees.—The most useful plants for anti-malarial arboriculture are those which grow most rapidly under the different climatic and geological conditions met with in this country. In the cultivation of such plants on a large scale, however, trees which will be remunerative should be chosen. Pines of various species have also been used and recommended in this country. Casuarina (*C. equisetifolia*) and *Nim* (*Azadirachta indica*) are the most useful and rapidly growing trees found in malarious districts. Chrysanthemum, sunflower (*Helianthus*), the beautiful plant *Canna* (N.O. *Scitamineæ*), castor oil tree (*Ricinus communis*), *kiri* tree, etc., also act in this way. It is possible that these particular plants may have some deleterious influence on the life of the mosquitoes, but most authorities consider this very doubtful.

It may be said that in some malarious marshy places along the banks of rivers, deltas and shores, disforesting, levelling, draining and cultivation, would improve them. Cutting down trees and cultivation of the original site of these trees, has rendered certain malarious places healthy. On the other hand it is a well-known fact that the cutting down of copses and forests, without subsequent judicious cultivation of the denuded area, has transformed many large tracts of well-drained land into swamps and marshes. Trees should never be removed without thoughtful consideration as to the advantages and disadvantages of doing so.

Trees in belts or clumps, or even heavy shrubbery, placed between malarial localities and human habitations have constantly been known to act as a protective agency against malaria. They are natural interceptors of mosquitoes from their breeding grounds. Large plantations of sunflowers have been reported to act in this way, but their efficacy is very questionable.

One of the beneficial effects of the blue gum (*Eucalyptus globulus*) tree was supposed to arise from certain balsamic exhalations. One has personally seen certain species of Culex in swarms around quite young blue gum trees up the Huon River in Tasmania when the whole air was saturated with the smell of these trees. None of the preparations of eucalyptus are of any use either curatively or prophylactically in malaria.

The clearing of jungle, brushwood and undergrowth generally from the neighbourhood of inhabited houses is a useful anti-mosquito measure, as all jungle of this sort affords rest and shelter for anophelines. Such clearing also permits of more rapid drying of the soil by the effects of the sun.

Rice-cultivation should not be allowed within a mile of towns or cantonments.

MEASURES FOR THE REMOVAL OF BREEDING GROUNDS OF MOSQUITOES.

General remarks.—In the campaign against mosquitoes, larvæ in their breeding grounds are much more readily attacked than the fully developed and flying insect. Adult anophelines by their seclusion and nocturnal habits evade detection in many ways, and can never be destroyed wholesale. Hence in all anti-mosquito measures it is the breeding places of mosquitoes to which most attention is given.

One of the factors that dominates anti-mosquito measures of the present day is the distance of flight of anophelines, because it is the area within the normal distance of their range of flight to which we direct attention in endeavouring to effect the destruction of larvæ and abolish the breeding grounds of mosquitoes. It must be frankly confessed that up to the present time we have no definite knowledge of this. The scientific entomologist who investigated this question in the Panama Canal Zone placed the limit of flight at 200 yards, and on the basis of this observation all anti-mosquito measures were originally carried out,* but later they were based on a 400-yard limit of flight.†

Certain carefully carried out observations in India have shown that the distance of flight is under ordinary circumstances about half a mile—this is the distance laid down by the Malaria Commission of the Royal Society—but it has been shown that under certain (probably exceptional and abnormal circumstances) anophelines may fly farther than this. It has been suggested that during the intensely cold weather of Northern India anophelines may yearly migrate southwards *en*

* *Journal of Tropical Medicine*, 15th August 1908, p. 251.

† *Journal of the Royal Army Medical Corps*, September 1908, p. 289.

masse, to return when the meteorological conditions are more favourable. There is no proof of this and facts are against such a supposition.

For the practical application of anti-mosquito measures in endemic malarial areas we are obliged to act upon some limit of flight of anophelines, and for the present we fix that limit at half a mile. The number of anophelines that under ordinary conditions operate in the dissemination of malaria at a greater distance than this is probably very small.

Marshes, jheels, irrigation canals, rivers, etc., at a distance from towns and cantonments are frequently incriminated as factors connected with local malaria without any foundation in fact, and in some instances large sums of money have been wasted in endeavouring to remove breeding places that were in no way concerned with the local malaria.

Removal of breeding places of larvæ.—The most effectual way of decreasing larvæ is removal of their breeding places* and the most comprehensive way of carrying this out is lowering the ground water level by drainage. The next most generally applicable method is that of drainage of these breeding grounds individually. This latter is a method which can largely be employed in endemic malarial districts, often without any costly engineering works. It is also a method which may be useful in large areas.

Many districts in which severe endemic malaria prevails, a certain amount of drainage on a small scale is practicable with comparatively little trouble, although, as a rule, in such cases, the question of expense would have to be faced, if any considerable reduction of malaria were aimed at. In connection with these localities CELLI states that "such methods (drainage) for the destruction of mosquitoes, while exceptionally soluble, will only be practically so when economic interests desire it."

The abolishment, complete or partial, of breeding places of anophelines is the most generally useful measure, especially in isolated towns, cities, villages and houses. In such places all house-holders should be responsible for the absence of mosquito breeding places from their compounds or premises. In every house in endemic malarial areas, efforts should be made to abolish all breeding places.

Disused springs and wells should be covered and rendered inaccessible to mosquitoes, and every possible collection of standing water should be abolished and filled in. The banks of small streams should be kept properly graded and cleared of grass and weeds, so that no opportunity occurs for water-logging in irregularities, or for aquatic vegetation thriving.

* The characters of the various breeding grounds of the different species of malaria-bearing anophelines met with in this country have been dealt with in the Section on ANOPHELINES, p. 62, *et seq.*, to which the reader is referred.

In places with a limited number of breeding grounds and a small rainfall, and where there are no irrigation canals, the doing away with breeding grounds is a comparatively easy task.

"A year's careful study of the breeding grounds in the suburbs of Calcutta showed that both the tanks, and still more the unlined roadside drains aggregating to many scores of miles in length, also breed abundant anopheles. It is quite impossible for municipalities to find funds for lining or levelling these drains, or to keep them continuously kerosined to destroy the larvæ; the attempts to do so having had to be abandoned in urban areas in Lower Bengal, while they are still more impossible in rural areas which contain the vast majority of the teeming population of this part of India."*

Of the simpler anti-mosquito measures the most comprehensive in its effects, and the most generally useful, is that of doing away with all stagnant collections of water in the neighbourhood of private dwellings, villages, towns, civil stations and cantonments, by filling up hollows and irregularities or by draining them.

Scooping out of larvæ from ponds, etc.—In small ponds it is sometimes easy to deal with larvæ by brushing them out with a broom, or scooping them out with a tin attached to a long handle on the bank to get the full effects of the direct rays of the sun which soon kills them. In streams with pools it is easy to brush them out along the bank, or drive them into the middle of the stream, where fish and other enemies may assail them. Netting larvæ is a laborious process and on the whole cannot be recommended.

Filling up of "borrow" pits.—The filling up of all "borrow" pits formed by excavating earth for building purposes is most important—these are the most fertile sources of breeding ponds and pools of anophelines around inhabited areas in India. One could name several large Indian cantonments where the chief breeding grounds of anophelines are old and recent borrow-pits, large and small, forming varying-sized "tanks" or excavations. The creation of borrow-pits should be prohibited, and wherever possible they should be filled up flush with the surface. Where there are a number of small borrow-pits and one larger one, the smaller might be filled up from the larger one, and this latter banked up and dealt with as an isolated feeding ground until such time as it could be filled in.

DESTRUCTION OF LARVÆ.

Larvicides.

"During the aquatic stage of the existence of mosquitoes, their powers of resistance differs—the eggs are moderately resistant, the young larvæ possess very little power of resistance, whereas adult larvæ

* Major Leonard Rogers, I.M.S., *Fevers of the Tropics*, p. 237.

especially nymphs are very resistant" (CELLI). The nymphal period is however comparatively evanescent.

The chief agents employed as larvicides are certain vegetable products, aniline dyes, and kerosine oil.

Petrolege.—The process of *petrolege* was commenced in the United States of America by O. HOWARD in the year 1892. If we exclude the abolishment of small breeding grounds of mosquitoes by drainage, or filling up with earth, petrolege is probably the most extensively employed anti-mosquito measure in this country at the present day. The total amount of money spent on kerosine oil for this purpose is considerable.

A mixture of kerosine oil and pesterine is the most useful and efficient larvicide for this country, and, on the whole, the most economical for dealing with small collections of water. It is fatal to all kinds of insects, and is harmless to vegetation.

Effects of petroleum.—Petroleum (and all oils) act mechanically only, by intercepting the air from larvæ which need atmospheric oxygen Larvæ under normal conditions come frequently to the surface to breathe. The stratum or layer of oil prevents any interchange of air in the larvæ; the openings of the breathing tubes are filled with the oil, the larvæ sink from removal of the surface tension, and are suffocated and drowned. If, however, the entire surface is not covered, space is left for access to air by larvæ and they survive. Nymphæ, which are more resistant to chemicals dissolved in water, are less so to a surface covered with oil, and die sooner than larvæ under this circumstance. This is, as would be expected, as they need more oxygen than the larvæ, and normally they have to come to the surface more frequently to breathe than larvæ. Ordinary oils acts similarly to petroleum and kill larvæ in ten hours.

On applying kerosine oil to a surface of water it diffuses rapidly; a very small quantity will spread over a comparatively large area. The ordinary three-gallon tin full of kerosine oil is sufficient for an area of 100 yards square, or 10,000 square yards. This proportion should be used for all collections of water.

In the case of larger collections, the common or garden watering-can with a rose having fine perforations, answers well. The oil is to be applied uniformly along the windward side of the pool by a man, the latter walking some distance into the water if it is sufficiently shallow. The sprinkling should be done by long rapid sweeps of the can, a few steps being taken after each sweep. The oil diffuses rapidly and that of the different sweeps will soon commingle on the surface. The thinnest film is sufficient. In the case of moats around towns or fortifications an ordinary garden syringe will be sufficient to spread the oil

When the water is deep and the surface to be covered with oil large, the same process may be carried out from a small boat Canal beds in which the water is shut off periodically is a source of myriads of anophelines in vast tracts in India. In this case the oiling should be done after each flow of water through the channel, or an automatic dropper containing kerosine may be suspended over the canal.

Form of larvicide recommended.—I would recommend that equal parts of pesterine and kerosine oil be used to replace the kerosine oil now almost universally employed. It should be used on two consecutive days. This is the most successful larvicidal mixture in use at the present day. It is employed in Ishmalia, Cairo, the Panama Canal Zone, and has been extensively and successfully used by the Bombay Municipality.

Pesterine is crude petroleum purchasable from Messrs. Graham & Co., Bombay, in 4-gallon tins at Re. 1-4-0 per tin. In bulk it costs about Rs. 40 a ton. As a larvicide its action is much slower than kerosine oil. One great advantage of it is that its colour tells us whether it has been properly applied. It is best used with an equal part of kerosine oil. It is best applied by means of an ordinary garden spray. In this way the liquid may, when necessary, be caused to find its way among grass and weeds which otherwise break the continuity of the film and allow larvæ and pupæ to escape destruction.*

In connection with large tanks my experience is that applications of kerosine oil are quite useless. In numerous tanks in which it had been used during the preceding 24 or 48 hours, one has found anopheline larvæ, sometimes in large numbers. In many large tanks with steep well-kept banks and an absence of water, weeds and grass where kerosine oil had been used, one has failed to discover anopheline larvæ. This absence was not due to the kerosine oil, but to the fact that anophelines, who are surface feeders, do not favour deep tanks without any form of vegetation.

One has frequently observed that kerosine oil is of little use except in connection with small surfaces, pools, and, when liberally used, in artificial collections of water. One has repeatedly "dipped" successfully for anopheline larvæ in places that had been recently kerosined. Two constant factors are in operation against kerosine oil in open waters, drifting wind and evaporation.

Sulphate of iron as a larvicide has been tried with but little success.

Permanganate of potassium solution, unless in a high state of concentration, is useless.

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* I am indebted to Dr. C. A. Bentley, Health Officer, Bombay, for this information regarding *Pesterine.*

In practically all cantonments, towns, villages, and private residences, a large number of breeding grounds of anophelines can be got rid of. Where small collections of water are necessary, as in garden barrels, cisterns, tubs, buckets with water for extinguishing fire, the use of some oil is necessary twice a week. Oiling is, however, at best, only a temporary expedient, and must be systematically renewed. Where water and labour are plentiful, emptying of artificial collections of water and exposure of the containing surface to the sun for a few consecutive hours once or twice a week are sufficient.

Creosote may be used instead of oils, but it is more expensive. A preparation known in the market as *Larvicide* has acquired a reputation in the West Coast of Africa, Italy and in French tropical and subtropical Colonies. It is said to kill all larvæ.

The best time for destroying larvæ is the winter and beginning of spring, when they are fewer in number in the water and new generations are not being developed. For hibernating larvæ two applications of oil, one at the beginning and the other near the end of the cold season, is sufficient. In the winter, also, wherever adult mosquitoes are found, they should be killed.

There is an enormous waste of kerosine oil in the way it is usually employed. One has seen it poured straight out of bottles, and from tin pots. When used for small collections of water such as garden cisterns, water butts, etc., a small water can, whose spout is provided with a small rose with very fine perforations, is required ; as stated above for larger collections, such as ponds, a larger can and a rose with slightly larger perforations, may be used.

As our knowledge of the habits of mosquitoes, of the localities in which and the time during which they lay eggs, increases, we will be better able to formulate methods to effect their destruction, but even under the most favourable circumstances, the getting rid of anopheline larvæ will always be an arduous task when carried out on a large scale.

The tropical aquatic fern called "Azollia" has recently been recommended as a remedy against larvæ in their breeding grounds. This is said to have the property of "spreading so rapidly that stagnant and running water in which it is planted is completely covered in a very short time." Small organisms such as mosquito larvæ which require atmospheric air are thus cut off from the air and suffocated Aquatic animals proper are said not to suffer any harm. It is not stated whether it is easy to eradicate the fern if so desired subsequently. It grows pretty freely on many of the tanks in the plains of India. It will grow quite well in any tank or very gently flowing water, and does not require any special treatment except perhaps the removal of other aquatics from the tank. It will not grow in drains or small pools. "We are ready to send small quantities of this fern wherever you wish to experiment with it. But we personally have very little faith in its efficacy for suppressing the mosquito over anything more than a very limited area." (Memorandum by Superintendent, Botanical Gardens, Calcutta.)

A new method of destroying mosquito larvæ has recently been described by S. de PUYBERREAN. By cutting the leaves of a prickly cactus, *Opuntia vulgaris*, and steeping them in water, a mucilaginous liquid appears on the surface in a few minutes. This liquid poured into water acts in a manner similar to petroleum ; when pieces of the plant are simply thrown on the surface of the water, a similar liquid forms although it is slower in its effects.

A reliable larvicide still a desideratum.—It may be said that no really practical and reliable larvicide has as yet been discovered. What is needed for general success as a larvicide is a soluble solid substance of lasting effect when used in small quantities, which is non-poisonous to man, cattle and horses, harmless to plants, inexpensive, and universally applicable in this country. It is possible that within a reasonable time a cheap larvicidal agent of this kind may be found. It is only by constant experimentation that we can hope to arrive at a suitable larvicidal agent or process. According to CELLI, in Europe the most suitable and most inexpensive larvicides at present are certain of the aniline dyes, but these have not so far been tried in this country. These aniline dyes are poisonous to many insects which live in marsh waters. Waters coloured with aniline dyes are not injurious to plants, so that they can also be applied to the water of rice-fields without damaging the crops. "Larvicide" is the most popular of the aniline dyes in use at present.

Larvicides of the vegetable kingdom.—The vegetable kingdom provides some useful larvicides. Infusion of tobacco leaves and the powdered unexpanded flowers of chrysanthemum and pyrethrum (*P. cinerariæfolium*), which form the bases of most insect powders, are powerful poisons to larvæ, killing them rapidly.

Fish poisons.—One or other of the fish poisons used by natives has been suggested as a mosquito larvicide. These poisons usually belong to one more species of *Derris*. "The roots are crushed and thrown into the water, and the milkey fluid from the fresh roots even in small quantities and much dilated will destroy the larvæ, and for small collections of fluid, cesspits, etc., is highly effective, killing off most forms of animal life, including (of course) fish." On this latter account it is not advisable on large collections of water.*

* DANIELS and WILKINSON'S *Tropical Medicine and Hygiene*, Part I, pp. 77, 78.

Aquatic vegetation in relation to mosquito larvæ.—All grass and weeds (except the various species of *Lemna* and *Anacharis* that grow in open waters) foster the breeding of mosquitoes.

Lemna (aquatic plants popularly known as "duck-weeds"), of which two species are commonly met with, *L. minor* and *L. gibba*, are decidedly unfavourable to the breeding of mosquito larvæ. Where tanks or ponds are only partially covered with these, however, anopheline larvæ may be found breeding prolifically.

Anacharis, or American duck-weed, occurs also in a few tanks and permanent collections of water as a delicate much-branched water-plant which is unfavourable to the breeding of anophelines. Its growth is usually so thick that they cannot move about the surface nor reach the bottom.

The *singhara* or water-nut plant (*Trapa bispinosa*), when the leaves cover the water thickly, are to some extent unfavourable to mosquito breeding. When, as is usually the case, the plant does not grow up to the edges of tanks or other collections of open water, or when it has been removed from the margins, anophelines may be found in great numbers. One has observed that of two tanks fairly adjacent, one densely covered with *singhara* and the other only partially covered, in the former there were no anophelines, in the latter there were swarms; the physical conditions of both tanks were otherwise, as far as could be noticed, identical.

Algæ even when disposed in a moderately thick layer over the surface of collections of water do not appear to affect the breeding of anophelines. *Mr. barbirostris* and *Mr. nigerrimus* appear to favour water containing these thallophytes more than other anophelines.

The water-lily (*Nymphæa*) does not appear to affect the breeding of anophelines in ponds and tanks in any way.

Weeds, algæ, and lower forms of vegetable life generally, may be prevented from growing in comparatively small irrigation and other water channels, by the use of a solution of sulphate of copper kept in iron or metal cans and provided with an automatic dropper. The strength of the solution required is about one pound to 10 gallons of water. This is an important auxiliary anti-larval measure, as algæ, and the lower cryptogams, afford both food and protection to larvæ.

A similar arrangement for the oiling of running water has been employed successfully in various places, but it is expensive and can only be recommended in cases where irrigation canals run through cantonments or other limited areas we wish to protect.

Considering the enormous quantity of kerosine oil that is employed for the destruction of mosquito larvæ, it is curious that up to date in this country no form of automatic dropper has been introduced. One has seen two forms of these, one in which the oil is contained in an elongated cylinder, the other that devised by Drs. E. H. and H. C. Ross in use in Cairo.*

Cultivation of fish for the destruction of larvæ.—Fish may be seen in tanks and in small and large collections of water in which there are crowds of mosquito larvæ, and this when the fish vary in size from an inch to 5 or 6 inches long. Recently one has placed very young fish (*rohu*) from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long in bottles with anopheline larvæ and the latter disappeared—in one bottle they had vanished in 7 hours, in another in 9. In another experiment 24 *Myz. culicifacies* larvæ were put into a bottle with three tiny fish of unknown species and they disappeared in 7 hours; in a third 19 mixed anopheline larvæ were placed in water with three young fish and the larvæ had gone in 5 hours. The first experiment was with fish and larvæ from the Tons river in Debra Dun; the other two with fish and larvæ from the Nakatya stream in Bareilly. Similar experiments with young fish from the Jumna at Muttra, and Ganges at Fatehgarh, were negative in result.

The *chilwa* (*Chilwa argentia*) has the reputation of being a destroyer of mosquito larvæ, and possibly it is so under certain circumstances, but one has on two occasions found anopheline larvæ in cisterns and tanks that had been stocked with them. One of these instances was peculiar, in that the cisterns were also regularly treated with kerosine oil—these were the fire cisterns in the ordnance part of the Fort at Agra. "*Millions*" whose natural habitat is the waters of the West Indian Islands are reputed to devour larvæ, and one has no doubt that if tanks could be stocked with species of these tiny fish accustomed to tropical waters, they would be very useful against mosquito larvæ. They belong to the family *Cyprinodontidæ* (either *Pœcilia* or *Gambusia*).

The existence of millions around the Islands of Bermuda and Barbados, and a few other West Indian Islands, is considered by some authorities to explain the absence of malaria and mosquitoes in these places.

The use of *gold fish* as devourers of mosquito larvæ has in some instances been successful; the success has not, however, been invariable, as I once collected a good few larvæ of *Myz. culicifacies* from a sacred bathing tank which was stocked with these fish.

Tadpoles are reputed to devour anopheline larvæ. One has noticed in many shallow tanks and collections of water, that when tadpoles were numerous, that is, when the bottom of the tank was almost black with them, few larvæ are found at that part of the tank, although they

* A full description of this automatic oil-dropper will be found in the *Annals of Tropical Medicine and Parasitology* for 1909 (Liverpool University Press).

may be found in other parts of the same tank where the tadpoles are few or absent. On several occasions one has placed tadpoles and anopheline larvæ in the same bottle, in some cases the latter rapidly disapproved, in others they remained without any decrease in their numbers.

Dragon-fly larvæ.—The cultivation of dragon-fly (*Agrionidæ*) larvæ for the destruction of mosquito larvæ has been recommended, and in a few instances in the United States, carried out. The larvæ of dragon flies devour mosquito larvæ greedily. One has on two occasions (one in Bareilly and one in Agra) found tanks that had all the characteristics of anopheline breeding places without any kind of mosquito larvæ, and the only reason one could assign for this absence was the presence in the water in both instances of a large number of dragon-fly larvæ, and in one of these instances winged dragon flies (who are also credited with consuming mosquito larvæ) were hovering over the tank in fair numbers. Dragon-fly larvæ netted from one of these tanks and placed in bottles with anopheline larvæ caused the latter to disappear in a short time.

The larvæ of water-beetles are also credited with being enemies of mosquito larvæ.

Mosquito brigades.—In practically all the operations needed for the removal of smaller breeding grounds of anophelines, and for the destruction of larvæ in small collections of water, mosquito brigades are usually sufficient. The work of mosquito brigades is applicable to a great variety of places in this country—towns, collections of villages, cantonments, jails, and all large industrial works and factories; one would emphasise the necessity of their employment wherever large gangs of labourers are employed on famine relief works, making of railway embankments, roads, canal works, tea gardens, extensive building operations, etc. In these latter cases half a dozen of the coolies under one headman could be taught their duties in a few days. A few gangs of such men working efficiently can prevent much of the malaria in aggregations of labourers. The same remark applies to troops who are obliged to encamp in an endemic malarial district *en route* to or from campaigns —a few soldiers placed on special sanitary duty may prevent hundreds of cases of malarial infection. The specific duties of mosquito brigades are detailed on p. 218.

F.—Prophylaxis of Malaria in Towns.

Surface drains.—In all new towns in India the laying of *a complete system of surface drains* forms the basis of all large sanitary measures. It is seldom possible to inaugurate such a system at once, but initially, a definite complete system should be planned out, and extended annually as funds permit. All the drains in the town should form part of the system. It will be necessary in originally planning such a system to have the opinions of an expert drainage engineer and an officer trained in tropical sanitary science to achieve the best results.

The drainage system should be such as to remove all storm water during the rains, refuse water from houses, industrial works, etc.

Public water-supply.—The next most important factor is a public water-supply conveyed in pipes, with hydrants distributed along the streets, and if necessary, in the houses. The drainage system should precede the water-supply, for if water comes into the town and has no definitely arranged outlet, the inevitable result is water-logging of the subsoil, with collections of water or pools forming breeding grounds for anophelines. There are some large stations in India where neglect of this principle of *drainage first, water-supply next,* has led to severe endemic and even epidemic malaria, where malaria was previously of a mild type.

Leakages from stand pipes and the collections of water arising therefrom are favourite breeding places of anophelines. Roadside drains, gutters and ditches are also favourite places for them.

The beneficial influences arising from a good public water-supply as affecting malaria are now easily understood—it removes all the collections of water from miscellaneous sources, domestic cisterns, wells, etc., that had previously been in use. Such a supply has also its influence in improving the health of the people by lessening the debilitating effects of water-produced maladies.

A good water-supply, good drainage and proper conservancy of towns and villages are the sheet anchors of preventing malarial disease. Our views as to their influence in reducing the incidence of malarial diseases have undergone no change in consequence of the established relationship between anophelines and malaria. Before the elucidation of the cause of malaria we knew that with these sanitary requirements places were rendered either free from malaria or it was greatly lessened. The fact that we now know the part played by mosquitoes in India emphasises the necessity of these sanitary needs.

Paving and levelling of roads.—Another important measure is the *levelling and paving of all roads, streets, and lanes,* preferably with some impermeable material such as *kankar*. The ordinary macadamising however answers almost equally well. Well-paved streets and courts prevent the formation of small puddles, runnels and pools during the rains.

Such sanitary works in new towns should not be undertaken without much forethought and judgment, nor with the expectation of forthwith converting a malarious into a non-malarious locality. Radical changes in the health of a town are never the outcome of a single year's sanitary work, and the best results can only be achieved in towns where the work of sanitary regeneration is comprehensively, thoughtfully, and scientifically carried out from year to year as the income of the municipality permits.

Excavating the soil.—Excavations have existed around Indian towns and villages from time immemorial and are to this day being created in all new towns and villages. Each house builder finds the earth required for building, in the immediate neighbourhood of the structure being created.

Contractors not to create borrow-pits.—No contractor, engineer. or builder should be permitted to excavate earth from any place closer than 1,000 yards of the boundary of the town, or at least half a mile from a village. It may to the present generation appear a severe law that imposes this necessity, when their fathers and forefathers were allowed to excavate earth whence they choose. In villages labour is always at hand and time is not a serious item, so that it is not so severe a hardship as it appears Towns are liable to grow so rapidly that if the distant limit named is not fixed, what is on the outskirts of the town to-day, will, ten years hence, be well within the town boundary. In bygone days people did not know anything about the mosquito-malaria relationship and could not be blamed for what they did, but now that this is universally accepted, excavations within the distance named should be prohibited by law.

Contractors are special delinquents in causing excavations by digging and removal of earth, stone, gravel, etc., from the vicinity of the building they are erecting. These excavations add materially to the cost of future sanitary work in towns and villages. One has seen many towns and cantonments in which such excavations are being systematically created at the present day.

In the early stages of the erection of villages and towns the first houses are built in any convenient spot, the rest follow promiscuously around them. In all new towns and villages an alignment should be made for streets and drains, and the sites for houses fixed, allowing for a sufficient space in streets for ventilation and light.

In starting all new towns a proper scheme for the laying out of houses, roads, drains, etc , should be thoughtfully worked out at its incipient stage before a single house is erected.

In existing towns a proper plan of the directions in which fresh houses, roadways and drains are to extend should be fixed upon and adhered to.

Filling up of "borrow" pits.—The filling up of all "borrow" pits formed by excavating earth for building purposes is important—these are the most fertile sources of breeding ponds and pools of anophelines around inhabited areas in India. The creation of borrow-pits should be prohibited, and wherever they exist they should be filled up flush with the surface. Where there are a number of small borrow-pits and one larger one, the smaller might be filled up from the larger one, and this latter banked up and dealt with as in the manner of an isolated feeding ground. Where the cost of doing so is too great the smaller ones could be drained into the larger by cuttings.

Swamps, etc.—Drainage of swamps, filling up of stagnant pools, closing of tanks near houses, clearing of undergrowth and of vegetation close at hand, and pouring oil on the breeding places of mosquitoes, are among the protective measures in operation in many towns in India at present. All possible breeding places of mosquitoes—pools, puddles, pots of water, tubs in which water may collect, garden receptacles, etc., should be kept under observation and control, and where necessary entirely abolished.

Streets and gutters.—Street gutters are not to be neglected; when allowing of collection of water they may be rebuilt, relaid, and cement-lined. Uneven roads should be levelled.

A special branch of the sanitary staff should be daily and continuously employed in systematically treating every pool, pond, tank, or drain with kerosine oil, and in such a manner as to cover the whole surface of the water lying in it twice a week during the breeding season of anophelines. The adoption of this measure should be supported by power to prosecute the occupier of any premises on which mosquito larvæ are found. Such legislation now exists in various malarious countries. The sanitary establishment of towns should see that owners and occupiers of houses and land keep their premises free from mosquito breeding places; keep water-courses and flood-water drains and culverts clear, properly graded, in good condition, and free from vegetation, and if pools are found in them to use kerosine; clear away undergrowth, long grass and jungle within the boundaries of the town, and make arrangements for clearing the land outside the municipal boundaries for 500 yards; fill up and drain excavations, pools, and low-lying lands, where water is likely to lodge. When marshes are at the foot of small hills and material from the hill can be easily obtained, it should be used to fill up the marshes, borrow-pits, etc. When this is done, care should be taken in regard to levelling the area from which the earth is removed. The municipality should limit the number of open drinking water tanks compatible with a sufficiency of supply, provide special tanks well-removed from huts and houses for washing and bathing purposes.

Table of minor anti-mosquito sanitary works.—The Sanitary Inspector or other responsible person should report daily to the Municipality or Health Officer the following points on a printed form* :—

	Sanitary Divisions.			
	1	2	3	4
1. Number of Inspectors employed ...				
2. Do. houses inspected ...				
3. Adresses of houses where larvæ were found				
4. Number of notices served to remove conditions causing the breeding of larvæ.				
5. Number of persons fined for having mosquito larvæ on premises.				
6. Number of linear feet of ditches cleared ...				
7. Do. do. dug and graded...				
8. Do. square yards of weeds, grass and vegetation cut and removed.				
9. Do. excavations filled up ...				
10 Amount of low-lying land raised ...				
11. Number of cubic yards of material used for filling up excavations.				
12. Number of men employed for 6, 7, 8, 9, 10 and 11.				
13. Number of persons fined for making new excavations without permission.				
14. Number of drains oiled				
15. Do. pools ,, ...				
16. Do. tanks and barrels oiled ...				
17. Do. men employed for oiling water tanks, barrels, drains and pools.				

The reports should be verified and some responsible officer should see that the work is done regularly, systematically, fairly, and with judgment.

All plans of houses, huts or other buildings to be erected should meet with the approval of the health officer or municipal authority as to site, structure, and relation to other buildings.

No drains should be interfered with, nor laid, nor connections made, without the permission of the Health Officer or municipal authority, and none should be permitted that do not form part of the general plan of the drainage of the town, which has been previously carefully decided on according to the contours and levels of the area to be drained.

During the sanitary regeneration of a town it is essentially necessary that other anti-malarial measures are put into operation at the

* Adapted from Prof. W. J. Simpson's *The Principles of Hygienic as Applied to Tropical and Sub-Tropical Climates*, p. 375.

same time, such as covering all wells with some mosquito-proof material —wire-gauze, zinc sheets or wood ; the same applies to all collections of water that cannot be otherwise dealt with, such as water reservoirs, tanks, garden cisterns, etc., and preventing the inhabitants storing water in receptacles that are not covered with mosquito-proof material.

When small *marshes in the immediate vicinity of towns* cannot be permanently dealt with by drainage, or filling up, the pouring of pesterine and kerosine oil over the surface is a measure deserving of attention in malarious places. Large marshes near towns must be dealt with by some radical measure.

Cesspools should be covered so as to render access of mosquitoes impossible, and they should be treated with kerosine oil once a week. Anophelines have been discovered near houses where no other breeding places than cesspools could be found.

It is probable that trees and the existence of houses of the suburbs, intercept mosquitoes that would otherwise gain access to the town, when the town itself ceases to afford them favourable breeding grounds.

An excessive number of trees in towns is to be discouraged, although this is a secondary matter, as trees are used for shelter by mosquitoes and not to breed in ; it is rare in towns to have holes in trees in which anophelines can breed. It may be necessary to have intercepting drains round the higher contours of the town.

The difficulties in connection with anti-malarial measures in a malarious town that is not provided with a public water-supply and is undrained are very considerable.

It is to the drainage works of Bombay, Madras, and Calcutta, together with public water-supplies, that these cities (in their interior at least) are so comparatively free from malaria—the districts around all three cities are very malarious. In inland towns the same would hold good—effective drainage by preventing the formation of collections of stagnant water will reduce malaria and mosquitoes, and in proportion as the latter will be reduced by methods of drying the soil, so will malaria diminish.

It has been repeatedly proved that malaria will undergo considerable reduction on the establishment of sound sanitation in a town—the introduction of a good water-supply, a well thought out drainage system, good arrangements for removal of excreta, good streets properly paved, proper rules for all new buildings, and a well organised establishment for carrying out all sanitary measures required. The persistence of intense malaria in large towns situated remote from marshes and river banks is a positive indication of sanitary maladministration.

It is doubtful whether any large city or town in India properly sanitated on modern principles and in accordance with our knowledge of the habits of anophelines could remain malarious, as the conditions of such a town are decidedly unfavourable to the continuance of anophelines.*

Mosquito brigades and gangs.—It is impossible to lay down any rule as to the number of mosquito gangs required for each town, as it largely depends on the area to be covered by the workmen, the number of collections of water to deal with, and the density of houses. What is necessary is that there should be sufficient workmen to visit each house and search out all breeding places for mosquitoes in the area at least once a week. In an ordinary Indian town it may be said that one gang of 15 men and one headman should be able to work over an area of a square mile. When the area considerably exceeds this, several gangs should be engaged, each gang doing a definite mapped out area.

The duties of the mosquito brigade men are to "visit regularly once a week the compound of every house and destroy every pool of water which can harbour mosquito larvæ ; to cover with a layer of kerosine oil every collection of water which is too large to be destroyed ; to remove all broken tins, pots, bottles, etc., which can contain water and harbour larvæ ; to instruct the inhabitants in the recognition of mosquito larvæ and the methods of destroying them ; to see that the bye-laws requiring that all fixed receptacles of water, cesspools, etc., should be made mosquito-proof are carried out, and to bring to the notice of their superiors every householder on whose premises mosquito-larvæ are frequently found ; during the rains to drain off quickly all superficial collections of water which can last sufficiently long to become breeding grounds of mosquitoes ; to endeavour to kill adult mosquitoes in houses, out-houses, and stables by fumigation with sulphur oxide or by other means ; to make observations on the seasonal prevalence of mosquitoes and their habits, and on every matter regarding which increased knowledge might aid in the extermination of these insects."†

In *towns and cities* the expenses connected with the reduction of anophelines will vary in accordance with the size of the area to be dealt with. In towns the cost is often small on account of the large number of people crowded on area, amongst whom the expenses would be divided by the municipality. Suppose it were a question of *drainage*. In a large town the drainage of an area of half a square mile will benefit a vast number of people ; the same length in a rural population benefits comparatively few. The expenses connected with anopheline-reduction varies with the extent of surface to be covered and has little relation to the population. On the other hand the expenses of case-reduction and for isolation are in proportion to the density of the population and not as the area.

* In this Section on *Prophylaxis in Towns* I am greatly indebted to Prof. J. W. SIMPSON'S *The Principles of Hygiene as Applied to Tropical and Sub-Tropical Climates*, p. 367 *et seq.*

† Major S. P. JAMES, I.M.S., *Malarial Fevers*, 3rd Ed., p. 93.

For cities, towns, and large stations, with dense populations, mosquito reduction is highly applicable, because in such places the cost of drainage (the usual chief measure) benefits a large number of people and can be better borne by them, the ultimate expense will probably be less than the cost of effective quinine distribution annually among so many, the measure will tend to reduce other diseases and annoyance besides malaria, and it can be carried out by the authorities on their own initiative without making demands on the populace to take drugs, use mosquito nets, and so on.

In the presence of severe malaria both mosquito reduction and parasite reduction should be employed together, and the other subsidiary measures referred to are to be used in special cases.

On the same principle extensive marshes in places where the population is great should be drained or deepened, and the edges levelled or the whole really filled up.

In estimating the cost of the anti-malarial measures whether in towns or districts we should include the salary of all medical officers and subordinates employed on the work, of the quantity of quinine issued gratis, of establishment for making quinine pills and for the preparation and despatch of these pills; pay of mosquito inspectors and of mosquito brigade gangs, implements required for the gangs, and incidental expenses of the staff, with a margin for contingencies.

G.—Prophylaxis in villages.

The reduction of malarial diseases of villages is one of the most important economic questions of this country. It is likewise one of the most difficult to accomplish, chiefly on account of its vastness, and because of the ignorance and poor circumstances of the rural population in general.

Four-fifths of Indian malaria occurs in villages.—Probably about four-fifths of the malaria of this country occurs in villages. The proportion of persons attacked in the army in India is, we know, about 20 per cent. A similar proportion in the civil population would mean that in the latter there are 75 millions of cases of malarial fever annually. Allowing that there are 25 millions placed under treatment in one form or another, there are left 50 millions who never get any treatment. We might argue that these victims of malaria are working out an immunity for themselves, but such a doctrine does not aid us in solving the problem of prophylaxis of rural malaria.

In the villages of endemic malarious places we find malarial fevers, enlarged spleens, anæmia, dysentery and diarrhœa in almost every house during the malarial season, causing conjointly a heavy mortality, especially amongst the young population, whilst periodical visitations of epidemic malaria and other diseases carry off many victims.

The vast majority of the people of India dwell in villages, and although the general sanitary principles for preventing malarial fevers are the same whether we deal with cities, towns, cantonments or villages, still the details by which these principles are put into operation are not identical. In the conduct of anti-malarial village sanitation it is important to remember that the people are absolutely ignorant of the very rudiments of sanitation. This gross ignorance of the people regarding the laws of health is the chief difficulty to overcome, next to which is the fact that they have from time immemorial followed certain insanitary practices, interference with which is considered to be an infringement of their liberty.

If any serious reduction is to be made in the general incidence of malaria in India, it can only be effected by case-reduction in villages, and by measures which will reduce the number of malaria-bearing anophelines in and around villages.

A great deal that has been stated regarding the anti-malarial measures in towns applies also to villages, with this difference, that most towns are financially able to meet the expenses connected with many of these measures, whereas there are no available funds in villages for such work.

As in the case of towns, a good water-supply, good drainage, proper conservancy, and a clear area around the outskirts, are the mainstays of preventing malaria in villages. When a village is about to spring up a scheme of its construction should be formulated, showing the direction in which all houses and huts are to be constructed, the alignment of the roadways and of surface drains should be fixed upon and adhered to.

The village headman should be responsible that no breeding places for anophelines exist within the limit stated or in the village itself. In very malarious districts he should be provided with quinine to issue to all cases of malarial fever and all children with enlargement of the spleen.

It is necessary to make the villagers through their headman understand the rationale of our present-day prophylactic measures of malaria. The principles underlying our preventive measures should be taught in all primary, middle class, and entrance schools, so that they will not be forgotten and ignored, as they would be were it merely the subject of one year's teaching. Placards might be printed in local vernaculars and posted in prominent places in all villages and schools. These notices should state in simple language the nature of malaria, that it is caused by parasites in the blood, the part anophelines play in its distribution, and the method in which quinine acts both curatively and prophylactically, and that the abolishment of the breeding places of nophelines is followed by a reduction of malaria. The placard should aive a picture of malarial parasites, and of culex and anopheline adults and larvæ, and briefly state how they are distinguished. One has seen this done in the Philippines, in Hong Kong and Southern Japan. A sample of a leaflet for distribution is given on p. .

Special measures recommended.—There are six special measures which one would recommend for all villages in the more severely endemic malarial districts :—(1) The treatment of all cases of malarial fever and malarial enlargement of the spleen with quinine issued gratis ; (2) the making of surface drains properly graded (even *katcha* drains) or removing rain water and refuse water generally ; (3) covering of all sources of water-supply with some mosquito-proof material—this material can often be manufactured from local sources ; (4) the filling up of all borrow-pits and excavations in and around villages for a distance of at least 100 yards ; (5) the prevention of all cultivation within this 100-yard limit and of wet cultivation within 200 yards ; (6) the keeping of this 100-yard area and the interior of the village free from mosquito larvæ. This latter could be carried out by the villagers, two or three of whom should take it in turns weekly or monthly.

The first of the measures suggested can only be carried out with the aid of Provincial Governments ; the other five can be carried out by the villagers themselves, and should be enforced by special legislation. One is fully aware that the limit of distance for cultivation is well within the range of the flight of anophelines, but it is as much as could be reasonably insisted on, and one is perfectly convinced that even 100 yards from breeding grounds would considerably reduce the anopheline population of villages. The manner in which this 100-yard area around villages is to be procured from the owners can scarcely be considered here.

Notwithstanding all the difficulties to be contended with one is confident that a great deal may be done to lessen the malarial index and reduce anophelines in villages by the conjoint efforts of the villagers themselves, and by pointing out to them the way in which they can reduce village malaria.

If we wish to make a radical impression on the malaria of India we must attack it in its rural homes. This is an enormous task, and at first sight, from its very dimensions, staggers the anti-malarial sanitarian. The fundamental cause of rural malaria is the universal existence of breeding places of anophelines. The essential cause of this is connected with the agricultural methods adopted in this country for a few thousand years. Practically all cultivation in India is carried out by irrigation from wells or otherwise without subsoil drainage, and such cultivation is continued up to the very village huts on all sides.

Drainage of agricultural areas.—Practically in all the historical instances of the eradication of malaria from Western countries such eradication has been effected by cultivation and drainage. In some countries, as in England, it took centuries to effect this ; in others the salutary change was effected comparatively rapidly. One is neither prepared nor qualified to put forward any radical remedy to remove the difficulty connected with the drainage of agricultural districts. One could make suggestions as to how, under the present system, anophelines might be reduced, but one considers that the best solution of the problem would be obtained by the combined efforts of an irrigation engineer, an agricultural expert, a malariologist, and an experienced Revenue Officer of the Indian Civil Service, to whom one would add one or two practical zamindars, forming a commission to inquire into the subject. The labours of such a commission would be arduous and involve much practical experimental work that would continue over some length of time, but one believes that they would considerably assist in a solution of this extremely difficult problem.

We should remember that the more comprehensive the drainage scheme, whether for marshes, irrigation, or collections of surface water, the longer it takes to produce any manifest results as regards case-reduction of malaria, but such a scheme, when once efficiently carried out, brings about either a complete eradication of malaria, or at least a considerable reduction of it from the locality. There are some modern instances on record in which a single drainage operation, somewhat inexpensively and rapidly carried out, has effectually removed malaria from localities, and that without the aid of other anti-malarial measures. Such instances are the drainage of a large marsh in the Island of Samarai in Papua, and the drainage of the European soldiers' barracks in the Island of St. Lucia, which latter was supplemented by clearing of a limited area of jungle, grading streams, filling up excavations, and rough canalisation applied to certain collections of water.

H.—Prophylaxis in Schools.

Free issue of quinine.—One of the most comprehensive methods of dealing with the endemic malaria of this country is that of endeavouring to eradicate malarial parasites from the blood of all school-going children by the curative use of quinine.

It has been repeatedly stated in this volume that native children are the main source of all malaria in this country, and that in endemic malarial districts a very large percentage of children from 0 to 10 years of age harbour malarial parasites in their blood. The school-going age may be said to be between 5 and 14 years, and one would apply the system of free quinine distribution to all infected children up to the age of 10 years.

By the systematic use of quinine in schools, we cure all infections and re-infections in these children, and considerably lessen the amount of residual malaria in the country.

Method of distribution of quinine to school children.—The method by which this may be carried out is part of the general system of quinine distribution which one has advocated for malarial districts. The quinine should be issued in tabllets or pills to schoolmasters for administration to all children in the morning before lessons begin. He should keep a register with a nominal roll of all children having enlargement of the spleen and all who are taking quinine.

Throughout the malarial season all school children suffering from malarial fever and with enlarged spleens should get a dose of quinine according to age every morning for three months. At the end of the malarial season the schoolmaster should send a summary of the facts recorded in the school register of malaria cases to the Civil Surgeon of the District, Deputy Sanitary Commissioner, or to the malarial authority of the province.

Nature of malaria : its causes and methods of prevention to be taught in schools.—The main facts connected with the causation and prevention of malarial fevers should be taught in all elementary schools. These might be posted up on placards printed in the local vernaculars with illustrations of malarial parasites, and of adult anophelines and their larvæ (see pp. 251, 259.)

Immediate precincts of school to be freed from breeding places of anophelines.—The precincts of the school should be free from all breeding places of anophelines, and all vessels containing water on the school premises should be protected by mosquito-proof coverings.

I.—Prophylaxis in Military Cantonments.

Importance of anti-malarial measures in cantonments.—It is impossible to emphasise too strongly the importance of anti-malarial measures in cantonments in India during peace times. The vast majority of cases of malarial fever occurring on field service are those in which initial malarial infection was acquired in cantonments.

The malaria of cantonments is to a large extent bred in the human occupants and anopheline population of cantonments. One is aware of the fact that there are exceptional stations in which this statement is only partially true, as for example in the British Infantry lines in Agra, where one found that the breeding places of anophelines were chiefly in villages and a brick factory from 500 to 800 yards to the south of the barracks and outside cantonment limits, but in the main the statement holds good.

There is a considerable amount of malaria amongst native children in cantonments. Of 3,884 children examined one found an average of 60 per cent. with enlarged spleens, and an endemic index of 40 per cent. Even in European Troops' children the spleen index was found to be 32 per cent.

European Troops are exposed to malarial infection in various ways, through attacks of anophelines infected by both European and native children, punkah coolies and followers generally; by visiting in the evening bazars, coffee shops, soldiers' homes, Army Temperance Association, rooms, and on " sentry go."

The detection, isolation and specific treatment of the infected soldiers are, as in other communicable diseases, of great importance in malarial prophylaxis.

Relapses occur when previous infection is not eradicated by proper treatment. In order to prevent relapses a prolonged course of treatment is required. The course of quinine treatment one would recommend is that laid down on pp. 159, 160. All troops and followers known to be infected by malaria should be subjected to this course of quinine treatment, or some modification of it, for not less than three months. An occasional dose of quinine taken irregularly is not sufficient—it is a delusion and a snare to consider that a dose every now and then when one thinks of it will prevent a recurrence of malarial fever.

In most stations malarial patients are now isolated in special wards and supplied with mosquito curtains; in many instances the whole of the wards in hospitals are made mosquito-proof by wire-gauze doors and windows.

Relapses can be prevented.—Relapses in soldiers and all other bodies of men under discipline in this country can, and should be controlled. The same does not apply, of course, to cases of latent and masked malaria, which are, as a rule, only discovered by accident. They, however, form such a comparatively small proportion of the cases of malarial infection that in the question of general prophylaxis they may be neglected.

The method of treating malarial fever cases with quinine for a week or two only is one of the many reasons for the continuance of malarial infection amongst our troops. Under such treatment the administration of quinine is discontinued just at the time when the patient is most infectious to others through gametes in his blood. The real way to treat malarial fevers in regimental hospitals is to keep the patient in hospital and under quinine until after careful search gametes are no longer to be found in the peripheral circulation. When this stage is reached the man can no longer, for the time being, communicate malaria to others through anophelines. In all prrobability gametes continue in certain internal organs—spleen, bone-marow, brain capillaries, etc.—long after they cease to be found in the peripheral circulation. It is these gametes, or some other unknown phase in the life of the parasite, that require to be eradicated, and until this is effected, the infected person is liable to relapses, that is, to recurring paroxysms without re-infection.

Admission into hospital and isolation of cases of malaria.—All known cases of malarial fever should be admitted into hospital—they should not be "detained" or allowed "to attend." This is very necessary in native regiments where the men on returning to the lines infect their comrades and frequently get re-infected themselves, there being always, in the malarial season, abundance of malaria-carrying anophelines present and infected native children. The advantage of remaining in hospital is emphasised when, as is now the case in many instances, the hospital is provided with mosquito-proof wire-gauze doors and windows. When malaria becomes epidemic, and the hospital accommodation insufficient, the overflow cases should be put into tents and not allowed to return to the barracks which only serves to perpetuate the epidemic.

All soldiers suffering from known malarial infection should be treated with quinine continuously for at least three months after the last paroxysm. When, as is the case during the malarial season, re-infection is liable to occur, the necessity for such treatment is emphasised. Were this done there would, I believe, be very few cases of relapses in the late winter, spring and summer months. *There should in troops be no residual malaria.*

All cases of malaria taking quinine curatively should get their quinine *at the hospital* daily for three months; this enables the medical officer to see the men regularly.

If the treatment of relapses begins after the malaria season is over a three months' course is, as a rule, sufficient. The occasional failure of even this lengthy course is no justification for its condemnation. When in any case there is an unusual amount of residual enlargement of the spleen it is advisable that quinine be given curatively for four months at least, no matter what the period of the year is in which it is commenced, and should the end of this course arrive during the malarious season these cases should, like all other men, get quinine prophylactically.

In malarial stations in many cases European Troops during the malarial season may with advantage be removed into camps well away from native towns and bazars, on the principle of segregation of the healthy (see pp. 174—176).

The keeping of European Troops in hill stations until the malarial season is over is a measure that is of considerable advantage to efficiency.

Prophylactic issue of quinine.—During the malarious season quinine should be issued prophylactically to all troops and followers in cantonments.

When to begin prophylactic issue of quinine.—When all cases of malaria in units are admitted, and such admissions reach from 2·5 to 3 per cent., I consider the prophylactic issue is justifiable. The longer it is delayed after this the higher will the percentage of fresh infections become progressively during the malarial season. One would not lay this down as a hard and first rule for adoption. There are circumstances when a prophylactic issue should be made irrespective of the percentage of admission, *e.g.*, on manœuvres at the end of autumn when in a district known to be malarious, or in barracks when there is a sudden rise in the malaria of the civil community around. Nor can the percentage named be adopted in all regiments at present, as in some the cases of malaria actually admitted are 3½ times less than those "detained." Assuming a uniform distribution of cases in barracks, any greater percentage than 2·5 or 3 means that one or more men in each barrack room are infected, and that through them, in the presence of anophelines, malaria will rapidly spread by infection acquired in the barrack. Under ordinary circumstances such spreading of malaria does not occur through cases in the barrack room of European Troops, but through the infected anophelines from married quarters and followers' huts invading barrack rooms.

The effect of the percentage of cases of infection in influencing the incidence of malaria may be seen in every endemic malarial district. When the prophylactic issue is postponed until the percentage of cases to strength reaches 5, the effect on the incidence for some weeks will be comparatively insignificant. The men in barracks are then in all probability infecting one another through malaria-bearing anophelines. In such instances the maximum prophylactic doses of quinine should be commenced at once, *viz.*, 5 grains daily for 6 days and 15 grains on the 7th day every week, or 15 grains on two consecutive days weekly. The condition of malaria in the civil population is another useful guide as the time to begin quinine prophylactically. In troops, as a rule, the maximum incidence occurs later than it does in the civil population of the same stations, the number of residual cases of malaria being greater in the latter than in the inhabitants of cantonments. In practically all instances in which they are taken it will be found that the spleen index and endemic index of the civil community in the neighbourhood of cantonments is higher than in cantonments.

Most effective method of using quinine prophylactically.—One's personal experience is that the best prophylactic dose of quinine during the malarial season where malaria is comparatively mild is 5 grains daily; where it is severe, 5 grains daily for 6 days and 10 grains on the 7th day weekly, and where it is very severe, 5 grains for 6 days and 15 grains on the 7th day weekly. With these three degrees of malarial intensity it is probable that the results of 10 or 15 grains once a week, 10 grains twice a week, and 15 grains twice a week, in the last two cases on consecutive days, would be slightly inferior to those recommended above.

Personally one does not approve of Koch's "long interval prophylaxis", and in stations with severe malaria I consider it inadvisable.

The great objection to the daily use of quinine as a prophylactic to troops is that connected with its administration under responsible supervision. One has, however, seen it carried out in several regiments without the least trouble. Tablets are much more popular than solution of quinine. The great advantage of the five-grain dose is that it never has any deleterious effect and never cinchonises.

All children in cantonments with enlargement of the spleen should get a three months' course of curative quinine treatment, receiving a dose daily.

When anti-mosquito and anti-larval measures are impracticable or hopelessly futile, our methods of prevention are limited to the use of quinine prophylactically, segregation, and mechanical defence against mosquitoes (mosquito curtains) of healthy and infected alike and complete treatment by quinine of all malarial cases to eradicate the parasite.

Eradication of malaria from children living in cantonments.—In a recent report on malaria I wrote: "I would strongly recommend that all children up to 10 years of age (including those of European troops) living in cantonments, be given quinine curatively for a period of three months during the ensuing year. If on account of the expense all such children cannot be given it, I would recommend that every child with enlargement of the spleen be given it for that period. This course may be commenced at any period of the year. Say it is begun on the 1st January, by the end of the year its effects on the malarial incidence in troops would be ascertained. The object aimed at is to eradicate malarial parasites from these children. This three months' treatment would only be necessary once, for although there would in succeeding years be once more a gradual rise from a low spleen index to a higher, the rate of this rise depending on the assiduity with which cases of malaria occurring in children were treated, the effects would last for some years at least. When the spleen rate in any future year reached 25 per cent., the method, in possibly a more perfected form, could be adopted again. I would here plead for a trial of this method and that it be carried out under rigid supervision and in a way that will not wound the susceptibilities of the parents."

One has drawn up a scheme indicating what is considered the best general method of carrying out this eradication of malaria in cantonment children. It is possible that local circumstances may call for modifications of it. In all cases the details as to the methods of distribution in units requires thought, judgment and tact, so as not to arouse prejudice against the drug. It is advisable that Medical

Officers endeavour to explain to parents the advantages of the use of quinine to the children, and the objects of the continuous administration for the period of three months.

The drug will have to be taken to the different follower's lines and regimental bazars and a daily parade of all children held. This parade should invariably include all children, whether with or without enlargement of the spleen, for by this means any cases of malarial fever met with would be at once placed on the list of those to get a three months' course. The parents should not be relied on to administer the drug to children. In the case of European Troops' children, the parade for the inspection and issue of quinine could be carried out at the more central of the married quarters, and should be invariably supervised by a Medical Officer.

The method proposed is as follows:—

1. An indent for a three months' supply of quinine of 50 per cent. of the children of all units, including those of followers, should be submitted taking the average at three grains a day for each child. This is assuming that only half the children have enlarged spleen; in some cases the proportion will be lower, in most it will be higher.

2. A spleen index should be taken of all children in cantonments attached to each unit, a nominal roll of those with enlargement of the spleen being made at the same time. This should be taken by the Medical Officer in charge of units. From this the actual amount of quinine required would be made known. Say there were 150 children, including those of followers and combatants; this would mean that about an half ounce of quinine a day, and roughly three pounds for 3 months, would be required.

3. A regimental order should be published in units that *all* children are to parade daily at a particular time and place, and that all children with enlargement of the spleen or malarial fever are to be treated for three months, receiving a dose of quinine daily.

The nominal roll, which would give the ages, informs the Medical Officer as to the number of half grain and one grain powders, or the amount of mixture required for children up to 2 years. For those over two years pills or tablets can be administered. The dosage would be—

Years of age	Under 1	1	2	3 to 5	7	10
Dose in grains	½	1	1½	2	3	5

4. In the case of native units the administration should be carried out by the Medical Officer and the Hospital Assistant. With European Troops, by the Medical Officer attached to the unit and an Assistant Surgeon, or the Hospital Assistant doing duty with the Cantonment

Hospital. In large cantonments, a Hospital Assistant on special duty could carry this out under a Medical Officer.

5. At each distribution the nominal roll would be called and the name of each child on the roll, as it gets its dose, be ticked off.

6. I would also recommend that this quinine treatment of all children with enlarged spleen be supplemented by the use of an application of the red iodide of mercury ointment of the British Pharmacopœia, made with simple ointment from bazar ingredients. It is cheap, and such an application would appeal to the parents and give confidence in the whole course of treatment. The mothers could apply it to the children or the latter to one another. A brief monthly report of the progress of the work and its effects would be forwarded by Medical Officers of units to the Senior Medical Officer, and at the end of the three months, a more detailed statement would be submitted showing the amount of quinine and ointment used, the effects on the incidence of malarial fevers and on enlargement of the spleens in the children.

It would probably be difficult to obtain a snfficent number of one-grain tablets, hence for smaller children pills, powders, or mixture will be required. For infants quinine solution is the most convenient, in the proportion of one grain to two drachms of water.

I consider this curative treatment of all children living in cantonments by quinine for at least three months, that is daily dosage according to age for this period, and subsequently during the malarious season the use of quinine prophylactically, to be urgently necessary. The object arrived at is the eradication of malarial parasites from that portion of the cantonment population mainly harbouring them, and through whom, with the aid of malaria-carrying anophelines, malarial infection is to a large extent maintained in cantonments.

One is confident that if rigidly carried out in its integrity under responsible supervision, its degree of success will be considerable, and that, if even partially carried out, it will effect a marked reduction of the malarial incidence in troops.

Mosquito nets and mosquito-proof doors and windows.—In the case of European soldiers in barracks located close to native quarters and the breeding grounds of anophelines, when these latter places on account of the expense or for other reasons cannot be abolished, it is probable that the best method of prophylaxis is that of providing wire-gauze mosquito-proof doors and windows, or mosquito nets for beds, and the regular prophylactic use of quinine during the malarial season.

The objection made to mosquito nets is that during the hot summer nights they are warm inside and close out the wind. This objection may be overcome by allowing the men, after the monsoons have set in and the great summer heat subsided, to sleep in tents, located at least half a mile from any source of malarial infection. This is a compromise on the method of segregation of the healthy from those infected. In most parts of India as the hottest months are not the most malarious, and the nights are comparatively cool, this objection to mosquito nets does not hold good. In all probability if mosquito nets were issued to all soldiers free, they would be used and malarial fevers considerably reduced in the army.

When so issued their proper use and care should be made a matter of discipline. From personal experience one knows that soldiers willingly and intelligently use mosquito curtains provided. Many soldiers in different stations buy their own mosquito nets, in other stations this purchase is aided by regimental or institute funds. Hence it cannot be stated that heat prevents the use of mosquito nets. Nets are specially necessary for European troops when quartered in forts and other localities in the midst of native towns and cities, where anti-mosquito measures are impracticable. This is the case in such places as the forts in Delhi, Agra, Fatehgarh, Lahore, Ferozepore, etc. In such cases it is also very necessary to change the fort garrison as repeatedly as practicable—once a month at least.

The introduction of mosquito-proof wire-gauze doors and windows for barracks in malarious stations would, on the whole, be probably one of the most economical ways of reducing the admission rate for malaria in European troops in this country.

No matter what form of mechanical protection is provided one would emphasise the necessity of continuing such minor works as can be carried out by mosquito brigades, especially the abolishment of all small breeding places of mosquitoes, filling up hollows and borrow-pits, draining off small collections of water, grading ditches and keeping them clear of weeds, oiling pools that cannot be removed, etc. This work should be in the hands of the Cantonment Committee and superintended by the Sanitary Officer of the station under the orders of the Senior Medical Officer. Anti-mosquito measures are in many stations regarded as impracticable owing to the difficulties of dealing with rice fields, irrigation canals, and other large masses of water in and around cantonments. In some cases the efforts of cantonment authorities are rendered futile because the breeding grounds of mosquitoes are near cantonments and under the jurisdiction of civil municipal commissioners who will not co-operate.

Prophylactic measures against malaria in cantonments should be independent of the measures adopted by the civil community. In the case of a regiment, company, troop or battery living in quarters located near native bazars in civil lines, and close to numerous breeding places of anophelines in such lines, anti-malarial measures to be successful must be independently carried out. This is a question affecting the anti-malarial and anti-mosquito measures of almost every large cantonment in India.

Punkahs are used in all European barracks and help to keep off mosquitoes, but they are certainly not a reliable protection against mosquito bites. In many stations in the United Provinces and Punjab such as Meerut, Delhi, Peshawar, Rawalpindi, etc., punkahs are stopped before the end of the anopheline season on account of the cold nights.

Rational hygienic living as an aid to prophylaxis of malaria.—To maintain good health, however, in malarious stations, all other precautions as regards personal hygiene are to be adopted, temperance in eating and drinking, abundance of healthy exercise, good and wholesome food, protection from chills, etc. These are dealt with under *Prophylaxis in the Individual.*

In all cantonments printed slips regarding the causation of malarial fevers and describing methods of prophylaxis should be distributed to all inhabitants and posted in conspicuous places. The main points to be alluded to in such leaflets are given on pp. 250, 251.

Repeated changes of troops from malarial to non-malarial places may have the effect of introducing endemic malaria into the latter, or of making slightly malarial localities highly malarial. There have been several instances of this in cantonments in late years.

Malaria in the Army in India is usually mild.—In military life in India, except in a few stations, we do not see the more virulent effects of malaria, nor the results of chronic and repeated malarial infection such as one meets in villages in endemic malarial districts, for the simple reason that amongst our troops severe malarial infection is at once brought under treatment, and relapses and re-infections are, to a certain extent at least, kept under control by periodical doses of quinine in cases of known infection, and quinine prophylaxis when general infection threatens. Our troops are better housed, fed, clothed and looked after, than the general native community of the country.

Malaria imported by returning furlough men.—In the question of general epidemiology and prophylaxis the amount of malaria met with amongst our European troops in India is comparatively infinitesimal, and the number of such troops that acquire malaria from one another through anophelines is probably small. The same cannot however be stated of our Native Army. While the latter occupy our barracks, even in stations that are endemically malarious, we should, by all the measures at our disposal, be able to prevent malarial infection becoming widespread. This does not hold good with those who leave their regiments to go on furlough yearly. Each native regiment is allowed to send 15 to 40 per cent. of men to their homes for several months every year. They either in going and coming from their homes have to pass through intensely malarial zones (as occurs with the troops of all our Gurkha regiments), or their homes are situated in endemically malarial places which is the rule. The same holds good with all recruiting parties going to and returning from these places, and with recruits coming from them. The return of these men (except in non-anopheline hill stations, as in the case of Gurkhas in the higher hill stations) serves to disseminate malaria amongst other men of the corps through anophelines, and where there are European troops in the station, probably to these also. The obvious remedy here is to allow men to go to their homes only during the non-malarial season and to carry on recruiting during this season also; or to provide them with sufficient quinine to be used prophylactically throughout the period they are on leave or on duty. When quinine is thus provided full instructions as to how it is to be taken, and if it is found that it is not used, this should be dealt with as a disciplinary measure. My personal experience of the use of quinine in this way is that it is very unsatisfactory and only influences the malaria to a small extent. It is better to examine all returning furlough men for malaria and treat all cases of infection found with quinine for three months.

Medical inspection of troops and followers before going on field service:—By regulation every regiment must be medically inspected as to its physical fitness before going on service The medical history of regiments should be examined as regards malaria. All men with a strong malarious history should be rejected, not only on account of their being temporarily "unfit," but because in the presence of anophelines, they are a source of infection to others. All followers must also be examined. They are much more likely to be infected than the troops as many of them live in bazars. Previous residence in the hills is a point in favour of sending a regiment on a campaign. One could quote numerous instances from the records of campaigns in the Indian Empire, where the advantages of this were demonstrated.

Campaigns, marches, or journeys through malarious districts should, when practicable, be undertaken during the known non-malarious months.

A large number of the permanently established camping grounds on the main roads between stations are located adjacent to native villages, and are therefore, for reasons already stated, sources of infection to troops occupying them during the anopheline season. Most of these camps were fixed upon antecedent to the establishment of the mosquito-malaria hypothesis. Camps thus located are convenient as regards water and supplies generally, but we should be aware of the risks when locating troops in them. Quinine prophylaxis is often required under this circumstance.

One can recall instances of the ordinary selected regular camping grounds for troops on the march from one station to another where these conditions prevailed and which accounted for most of the cases of malaria occurring among the soldiers.

Prophylactic issue of quinine on field service.—If the malarious tract covers more than one day's march, a prophylactic ration of 5 grains of quinine should be given every morning, beginning with the morning of the first march. So long as the force continues in the malarious region, this prophylactic ration of quinine must be continued. It may, in some very malarious places, be necessary to give 10 grains daily.

Tablets are more popular than mixture and, all things considered, are the most practicable method of using quinine on field service. It is specially necessary that the men should have a meal of coffee or tea and some solid food each morning before marching. When a malarious country has to be marched through, a full stock of quinine for prophylactic use should be supplied to regimental hospitals, field hospitals, and field medical depôts. In reputedly malarious regions the force should avoid, when possible, camping in the neighbourhood of villages and towns—the youthful population of such places and many of the adults are infected with malaria. Anophelines of the malaria-bearing species are necessarily present, and if our camp is within their range of flight, troops must get infected. In such places the local residents should be excluded from camps, and our men prohibited from entering the villages or towns.

Latent malarial infection always with the force.—In taking the field it may be said that, as in the case of enteric fever, we have always a large number of cases of malarial infection in the force, who, in the presence of malaria-bearing anophelines, are a source of danger to others. This arises partly from the way in which we treat cases of malarial fever in the army in India. The ideal way of treatment in a regimental hospital would be the complete isolation of malarial fever cases from others by day and night in mosquito-proof wards, the administration of quinine, and its continuance until all the gametes (sexual forms of the malarial parasite) have disappeared from the peripheral circulation. Even then it is probable that some cases of latent malarial infection would escape, as gametes may sometimes not be found in the peripheral circulation for weeks, but are present in internal organs such as the spleen, liver, red marrow of bones and brain.

Main anti-mosquito measures for cantonments.—The chief anti-mosquito measures required in cantonments are included in—rough canalisation of rivers, streams, irrigation canals and water-courses generally; levelling, grading and embanking of rain-water channels, ditches and roadside drains; filling up of tanks, borrow-pits, excavations and depressions generally; covering of disused wells; covering, or periodical emptying, or kerosining water cisterns; filling up excavations for bullock runs; kerosining twice a week all small collections of water that cannot be abolished; prevention of excavations for building purposes within 1,000 yards of cantonments; removal of brick factories to 1,000 yards at least of cantonment limits; and disuse of grass farms within 500 yards of barracks when these are near the breeding grounds of anophelines. Each of the measures enumerated is dealt with under a separate section more or less in detail. One would here only refer to a few that appear to be of special importance.

Rough canalisation of streams.—Where rivers run along cantonments it is possible by proper embankments and regulation of the bed during the seasons of low water to considerably lessen the facilities for the breeding of anophelines. One is constantly reading in reports that because a river or a large irrigation channel is on the confines of cantonments and town, it is useless to make any effort to reduce anophelines. This policy of allowing things to continue in the old way is one that is responsible for much of the inactivity displayed in regard to anti-mosquito measures.

Irrigation channels.—Where irrigation channels run along cantonments with various branches through regimental lines, as at Peshawar, Mardan, and many other places in the Punjab, something can be done by (1) placing an automatically acting dropper containing kerosine oil at the head channel; (2) grading and levelling the channel so as to maintain a flow of at least 2½ feet per second; (3) clearing it of all grass and weeds periodically. Weeds and grass may be prevented by a similar automatically acting dropper containing a solution of sulphate of copper (strength 1 lb. to 10 gallons of water). Where the cantonment can afford it, these channels should be made pucka; where not, then the men operating as a mosquito gang can keep it level, and by rough canalisation and proper grading maintain a uniform flow.

Brick factories.—No brick factory should be allowed within 1,000 yards of cantonments. The making of barracks for native troops and followers with pucka bricks joined by cement would do away with the excavations now made by the use of mud walls and sun-dried bricks. The initial cost would be greater but the outlay is justified from many points of view.

Rice cultivation.—Rice cultivation should not be carried on within a mile of cantonments.

Thatch roofs foster mosquitoes.—Thatch should not be used for the use of native troops or native followers' barracks. Thatch roofs harbour mosquitoes during the malarious season, and also serve as places in which they may either hibernate or æstivate during the non-breeding seasons, that is, in winter and summer. Tiles are preferable. Mosquitoes cannot stand the heat attained by tiles during the summer. During and for a time after the rainy season it is much easier to capture anophelines in a thatched house than in any other.

The creation of borrow-pits or excavating the surface soil for any purpose whatsoever should be strictly prohibited within 1,000 yards of cantonments—the nearer this limit is to a mile the better.

The construction of barracks should not be considered completed until every excavation within 1,000 yards created during such construction has been filled up and properly levelled.

Mosquito gangs in cantonments.—The mosquito gangs of cantonments are chiefly employed in kerosining large and small collections of surface water, disused wells, garden cisterns and fire buckets. Kerosining large bodies of water is a useless waste. The sphere of usefulness of mosquito gangs can be considerably extended. Important parts of their real duties are—filling up small and medium-sized borrow-pits, holes, excavations and depressions in the ground generally, including the shallower parts of large tanks; collecting old pots and pans, broken and discarded chatties, broken bottles, and anything in which water may collect; removing grass and weeds from roadside and other drains and ditches; levelling the beds of large and small katcha roadside drains and ditches, and collecting anopheline larvæ.

This work should be carried out systematically, the labour fairly divided amongst the men, the work regularly supervised by some responsible cantonment authority, such as the Cantonment Magistrate, Cantonment Sanitary Inspector, Sanitary Officer, Senior Medical Officer, and other members of the cantonment staff. These officials should be acquainted with all possible breeding grounds of anophelines in the station and allot tasks to the mosquito gangs.

Another use of mosquito gangs is that they keep people interested in the work of mosquito reduction in their compounds, and in anti-malarial measures generally. The success achieved also indicates how readily and inexpensively anti-mosquito measures on a small scale can be carried out in private bungalows.

In a mosquito gang of three men, one should be provided with a pick, another with a shovel, the third carrying the larvicide used, as well as wide-mouthed bottles for anopheline larvæ, when collecting these latter. These bottles should be ready labelled, and one of the three men should be able to write in vernacular where the anopheline larvæ were found. The more useful and intelligent of the three should be the headman, who keeps the gang at work and does the same work as the others, himself getting, say, one rupee a month more pay. All larvæ collected should be examined, in large stations by the Medical Officer in charge of the station laboratory, in small stations by the Sanitary Officer on duty or by Medical Officers of units.

Mosquito Inspectors.—One would recommend that for a year or so each large cantonment employ a man for ascertaining the breeding places of mosquitoes, capturing winged anophelines and supervising the work of mosquito gangs. This man would be the Cantonment Mosquito Inspector. These duties could be taught to any intelligent man within a fortnight. A staff of such Inspectors could be readily created out of junior Hospital Assistants, and, although expensive, it would in large cantonments be an economical measure in the long run. In their case the duties could be considerably extended and made more technical. They would ferret out every breeding place of anophelines, identify all larvæ caught, capture adult anophelines in native quarters of cantonments and in the neighbourhood of cantonments, carry out blood examinations, spleen indices, and thus localise the malaria in existence. The same men could as part of their duty issue quinine to all native children in cantonments and keep registers of these cases. To be of special use, however, the initial training of Hospital Assistants in these duties should be sound so as to make them conversant in a practical way with the problems associated with the prevention of malaria. It would be easy to arrange to hold a class for this training during the anopheline season in some large central malarious station. Such training would embrace the identification of the different species of anophelines of this country, their larvæ and eggs, methods of capture of winged anophelines, breeding outof anophelines from ova, demonstrations regarding the breeding places of anophelines, diagnosis of malarial parasites in fresh and stained bloods, methods of staining, the diagnosis of malarial fevers clinically, the action of quinine, the method in which it is used curatively in malarial fevers and prophylactically. The materials for such instructions are to be found in all malarious stations during the malarious season.

With the progressive decrease of breeding places of anophelines in and around cantonments there will, I believe, be a corresponding reduction in the amount of quinine that will be necessary for curative and prophylactic purposes in garrisons, and the amount of labour required to keep down the number of breeding places will become yearly less.

I would recommend that in every cantonment printed leaflets be distributed and placarded in English and the local vernaculars giving a brief and simple account of the essential causes of malaria, stating that it is due to malarial parasites in the blood, that these parasites are conveyed from man to man by certain kind of mosquitoes, that these mosquitoes breed in water, and that quinine kills the parasites in the blood. The leaflets should contain sketches of normal red blood cells, red cells infected by malarial parasites, adult anopheline and culex mosquitoes, and anopheline and culex larvæ in water, and a few words as to how to distinguish the winged insects and their larvæ. On pages 250, 251 will be found what one considers to be the essentials of such a leaflet.

J.—Anti-malarial Measures in Jails, Asylums, etc.

These places are often so located that it is impracticable to take into account the outside population and their environments, and the work of prophylaxis has to be carried out independently of what is done outside.

It is in no sense difficult to deal with the breeding grounds of anophelines in jails, asylums, etc., but it is not possible by the jail administration to deal adequately with immigrant anophelines. The chief obstacle in these institutions is fresh importations of malaria cases; the population of a jail is a moving one, people coming in and going out, whilst a large number of cases are relapses. The construction of the cells of jails is in most cases such that the limited space precludes the use of mosquito nets in the absence of artificial methods of ventilation.

The chief means at the disposal of jail administrations are those dealing with the smaller breeding grounds of anophelines within the premises and the use of quinine prophylactically. In every case coming into jail the blood should be examined for malarial parasites and the spleen investigated; every case of malarial fever occurring should be isolated in the hospital and thoroughly treated by quinine, thus endeavouring to eradicate malarial parasites from all prisoners. Quinine should be administered to the whole jail population prophylactically during the malarial season.

As with gangs of labourers on construction works, a certain number of the prisoners should be formed into a mosquito gang under a headman; and one or more intelligent men should be taught the duties of mosquito inspector (see. p. 236).

The same rules apply to lunatic asylums, modified, of course, for adoption to the conditions of asylum life.

K.—Anti-malarial Measures for Gangs of Labourers and Large Industrial Works.

Special measures advocated.—The anti-malarial measures to be adopted for all gangs of labourers or coolies employed on railway embankments, canal-works, road-making, bridge-construction, and on all large famine relief works, require in each instance to be thought out in accordance with the local conditions. A thorough inspection of the locality is necessary before determining any method of excluding malaria, and we should know the number and classes of labourers to be arranged for.

The area to be occupied by the work people should be parked out; a plan of the hut to be used should be drawn up and followed; a hospital shed should be erected; every coolie is to be examined especially as regards enlargement of the spleen, and if found suffering from present or comparatively recent malarial infection he should be isolated ; no case with actual enlargement of the spleen should be employed ; strict orders should be issued preventing all forms of excavation ; all persons with a history of recent fever and all infected persons should be given quinine for three months, all cases of existing malarial infection should be isolated in the hospital which should be at least 200 yards from the coolies' huts. All fresh arrivals should be similarly examined and dealt with. All cases of chronic malarial infection should be eliminated and sent to their homes. During the actual malarial season quinine should be issued prophylactically to all labourers, 5 grains daily or 10 grains on two consecutive days every week. This issne should be made under responsible supervision.

A short and simple set of anti-malarial rules should be drawn up. These should give in the simplest possible language the causes of malaria, explain that it is due to parasites in the blood which are introduced by mosquitoes, the way mosquitoes breed, and the use of quinine in preventing malarial fevers. These rules should prohibit the creation of borrow-pits and excavations of all kinds which may become the breeding grounds of mosquitoes, and direct the covering up of all water stored in the huts. The rules should strictly insist that every case of fever report sick at once.

A certain number of the men should be put on special anti-mosquito duty, their work being much the same as that of mosquito gangs employed in towns. The mosquito gangs should be under one of the headmen of the labour gangs, who should be taught the work of mosquito inspector. He should superintend the work of the mosquito brigade and report daily to the officer in charge. These men should be taught their work at the beginning by the Hospital Assistant or by the officer in charge. The number of men required will largely depend on the size and nature of the work under construction, character of the ground, and the area covered.

The class of persons employed in the construction works enumerated are illiterate, and usually of the lowest and most impoverished order of the community. Therefore the anti-malarial rules of the camp should be explained to them by the headmen of the individual gangs.

When the work is in a malarial district the site of the camps should never, when possible, be within half a mile of villages or bazars, or other habitations occupied by the local population.

As the work progresses and the camp moves on, the same measures should be enforced in every new site occupied, and all old sites should not be quitted until every possible breeding place for mosquitoes has been abolished.

All such gangs of labourers should be provided with a hospital, no matter of how temporary a nature, with a Hospital Assistant in charge, and where there are a number of such gangs in a district, a visiting medical officer should see that all anti-malarial measures are being carried out systematically.

Amongst such gangs all cases of severe malignant tertian should be sent to their homes if practicable, or arrangements made to send them to an adjacent civil hospital.

As with soldiers, so with coolie labourers and all gangs of men under control; when infected by malaria, treatment by quinine for a few days is a mistake, if malaria is to be eradicated. Each infected case improperly treated is a source of constant menace to his companions, and an added factor to the maintenance of malaria through the medium of anophelines.

It is a mistake to send healthy labourers from non-malarious districts to an intensely malarious one. Of men sent in this way a large proportion become saturated with malaria and useless within a few months. As examples of the loss of labour thus brought about are the Gurkha and Sikkim coolies employed on the tea estates in the Duars, etc.* When recruiting labour gangs for work in malarious areas it is advisable to select men from people already immunised by previous attacks of malaria in childhood.

One has investigated the malaria of two such collections of labourers, one in connection with the Bari Doab Canal works in the Hoshiarpur District, and the other in connection with the building of a railway extension in Assam, and in both these, there was every condition that could favour the rapid dissemination and intensification of malaria. One hazards the opinion that much of the malaria produced under these circumstances can be reduced and that at comparatively little cost.

One recognises that arguments (chiefly those connected with financial difficulties) can be brought against some of the suggestions for mitigating malaria in gangs of labourers enumerated above, but without entering into details one would state, apart from the enormous advantage to the reduction of the distribution of malaria in India effected, the actual saving in labour would to some extent compensate for the expense.

In all large industrial works or factories the plan of the huts to house the employés should be fixed upon and the area to be occupied planned out systematically. The entire area around these houses or huts for a distance of at least 100 yards should be cleared and levelled, and all possible breeding places for mosquitoes abolished. A hospital should be opened for ordinary cases and for the segregation of malarial cases. One

* This subject has been dealt with in the Section on the *Rôle of Man in the Distribution of Malaria in India*, p. 33, *et seq.*

would also recommend the establishment of a small mosquito brigade, who would deal with the breeding places of mosquitoes in the manner laid down.

It would be a wise economy to provide all employés with quinine free of charge, and to encourage its consumption as a prophylactic against malarial infection. During the malarial season there should be regular parades of the establishment for their doses of quinine, ten grains of which should be given on two consecutive mornings every week or five grains daily. One would here mention that in the Panama Canal Zone quinine is to be found in every café and on every restaurant table free to any one that wishes to take it.

In the tea gardens of Assam what has chiefly been relied on is the use of kerosine oil on waters in drains, ditches, and pools in the neighbourhood of the coolies' houses. Killing or driving out adult mosquitoes from the houses and huts of coolies infected with malaria, keeping a space around the coolie lines clear of jungle and low vegetation; and filling up of all holes and puddles. The chowkidars or watchmen are given tins of kerosine oil, and they are instructed to sprinkle it along the drains at the end of each shower. The oil is carried down by the running water to all the little hollows and inequalities wherever water collects.*

In the case of large isolated estates there should, when practicable, be a hospital for all cases of malarial fever, and where this is not possible, a method for having all hands employed systematically and regularly inspected, and all persons found to be suffering from malarial fever or enlargement of the spleen should be given quinine regularly for three months.

L.—Prophylaxis in Houses.

Construction of houses.—Houses in malarious localities should be constructed with special precautions. During the last hundred years in India in malarious districts there has been little change in the building of new houses, or in the restoration or rebuilding of old ones.

Mosquito-proof wire-gauze doors and windows.—In the planning of such houses the new views regarding the part played by anophelines in disseminating malaria should be kept in view. Mosquito-proof houses provided with wire-gauze for doors and windows are a great protection against mosquitoes. The subject is dealt with at pp. 177, 179.

Whenever possible the house should consist of two stories, in which case the ground floor should not be used as the sleeping-room. The bed-room doors and windows should be away from flower beds and vegetable gardens. The walls should be covered with some light coloured wash or light coloured paper—light colours are not favoured by mosquitoes.

* I. M. Gregorson, M.B., C.M., *Journal of Tropical Medicine*, 1st February 1909, pp. 31, 32.

The domestic species of mosquito, those that naturally seek the shelter of houses and huts, may be reduced by rigid attention to the cleanliness of the interior of the house. All unnecessary curtains and draperies should be removed; clothes should not be hung about on pegs, but folded and placed in almirahs or wardrobes; boots and shoes should be put into cupboards or left in a well-lighted part of the room—mosquitoes seem to have a special *penchant* for leather. Dark-coloured clothes, curtains and drapery are specially favoured by mosquitoes as their places of rest and shelter during the day time. There should be a minimum of furniture in the rooms, as when there are no more attractive places available, mosquitoes will hide under tables, chairs, sofas, and beds during the day to come out and feed on the occupants at night.

Use of fumigants.—The occasional use of fumigants is a useful auxiliary to larvicidal measures. When, in addition, houses are protected from the entrance of mosquitoes by wire-gauze doors and windows, mosquito-proof rooms, or mosquito nets for beds, they should be practically free from mosquitoes. In the absence of larvicidal measures such fumigation and mechanical protection is most useful.

In using any of the *fumigants* it is obvious that due precaution against fire should be taken, specially when live charcoal or wood is used to help the poison to burn. A rough kind of shield may be used by placing the brazier or earthern vessel containing the fire on a piece of sheet-iron, tin, or zinc, and preventing sparks flying by a metal sheet of the same kind in the form of a canopy suspended over the fire by means of a few piled-up bricks or stones on two opposite sides. The details in connection with culicidal fumigation are given on p. 182 *et seq.*

All gutters on roofs should be properly graduated and thoroughly well laid; this would prevent the lodgment of water or formation of pools; during the monsoons these gutters should be periodically kerosined.

Refuse water.—Water from bath-rooms and cook-houses should be conveyed away from the house by means of proper drains; it should not be allowed to flow over the ground in the neighbourhood of the house. All houses should be provided with a well-laid surface drain running around them, to carry away all water to the main or submain, and so prevent pools forming. All cisterns and tanks in connection with houses should also have a drain round them. Such drain should be brought into connection with the surface drains beyond the compound. All out-houses (servants' quarters, kitchens, etc.) should also be provided with proper drains.

Removal of undergrowth.—All compounds should be kept free from undergrowth. Shrubs, if indispensable, should be at some distance from the house. If tubs are considered necessary for storing water they should be covered with wire-gauze and emptied once a week or regularly kerosined. They should on no account be kept in the house. They are one of the most frequent abodes of mosquito larvæ.

Covering of wells.—All wells should be covered with wire net that is mosquito-proof. It would be a decided advance were all wells of Indian houses to be provided with pumps.

Filling up of hollows.—All hollows should be filled up. It is often a question as to where to get earth to fill in hollows. As a rule there are some slightly elevated plots in a compound that may be levelled and the earth used for filling; or the earth bank of a compound wall may be used Hedges of wire or bamboo are preferable. Earth walls of this kind only serve to obstruct drainage without serving any practical purpose. Where no available earth is at hand, it is possible to lower the general surface level a few inches without harm and use the material for filling up depressions and holes.

One of the most generally useful ways of emptying water from large hollows or borrow-pits is to cut a narrow channel leading from the hollow to the closest surface drain. Where a number of such small depressions are close together they might be drained into the largest and the latter kerosined if it cannot be emptied.

One of the best methods of protecting a house from the dust and glare of the hot weather is the maintenance of a well-kept lawn with a few trees around the compound, the latter, however, at a distance. The fewer the flower beds the better. The lawn should not be flooded with water but sprinkled with it once a day. In malarious places it is not advisable to have trees immediately around houses, for during the day they harbour mosquitoes which in the evening get into the house through the doors and windows, especially when the rooms are lighted.

All articles that can hold water such as old flower pots, old and empty kerosine oil tins, jam tins, jars, broken bottles, etc., should be carefully looked for throughout the house and compound, and either buried or thrown into some depression in the soil which it is desirable to fill in, or be removed by the municipal refuse cart.

The entire area around the house should be carefully inspected after a brisk shower of rain. It will then be noticed where water collects. These spots should be marked, filled up, and properly levelled.

Supervision of anti-mosquito measures.—The anti-mosquito measures around a house are easily supervised. All that is necessary is a walk round the premises twice a week to see that the permanent orders regarding the prevention of breeding of mosquitoes are carried out—that all the garden cisterns, tubs, barrels, and all collections of water are emptied and cleaned out once a week. Mosquito larvæ will not thrive in comparatively sterile water, and they cannot withstand the action of direct rays of the sun for a few hours. This small amount of trouble will go a long way towards preventing malaria, to say nothing of adding considerably to the comfort of being free from the attacks of mosquitoes. Where people in a town or a group of adjacent houses work together, it is possible to considerably lessen the number of mosquitoes in houses and in some exceptional circumstances exterminate them. In the majority of cases, however, we can only look for a reduction in their numbers, the extent of this reduction depending on the assiduity with which occupants of houses carry out the measures suggested.

Legal responsibilities of tenants.—All occupiers should be legally responsible that no opportunities are given to mosquitoes to breed on their premises. Beyond the compound walls it is the work of the municipal authorities to exclude breeding grounds of mosquitoes. In the case of houses, as in that of towns and villages, measures to be adopted should be thought out in connection with local conditions. The general directions given refer specially to the individual bungalows in civil and military stations, and the outskirts of towns. It may be that some of these recommendations cannot be carried out. Take, for instance, the case of an isolated well-built house situated on the margin of an enormous swamp into which several creeks trickle, or a house near a large tank into which the rain water of the surrounding area drains. The drainage of such a swamp, or the filling up of such a tank, which would strike at the root of the matter, would cost much more than the house itself. One's advice in such a case would be, if the house must be occupied during the malarial season, to provide it with wire-gauze doors and windows, or at least sleep in a mosquito-proof room, or under a mosquito net, and take quinine prophylactically.

In private houses that are rented the expenses which occupants are prepared to undertake will naturally depend on the length of time the house is to be occupied. Most officials in Indian stations are only temporary residents and will, as a rule, find it cheaper to adopt temporary measures, such as the use of kerosine oil on all small collections of water. Where, however, people are more or less permanent residents, such as business men in large presidency and provincial towns, it will be found that a moderate outlay on permanent anti-mosquito measures eventually compensates more than temporary ones.

Watering arrangements for gardens.—Canals, large and small, especially when katcha and their banks are irregular and not kept clear of grass and weeds, are popular breeding grounds for anophelines. They are specially objectionable and should never be allowed near private dwelling houses. They lead to heightening of the subsoil water level with all its risks in the production of rheumatism, pulmonary diseases, especially tuberculosis of the lungs, etc. The permanent resident is advised to eschew the use of irrigation channels in his compound; they may be a source of income to the professional cultivator, but as a rule are only a source of ill-health to the private resident who has them to water his flower garden. The possession of a garden is very pleasant, but one knows that the watering arrangements are a perpetual source of mosquitoes.

Water channels used for conveying water from rivers or irrigation channels to gardens and compounds are popular anopheline breeding places. Within his compound the owner or tenant is responsible for these. They cannot be considered nuisances, and compulsory drainage cannot be insisted on. Such channels usually only run for a few hours during each day, in which case they need but little attention as the sun kills the larvæ, but when collections of water spring from them, the owner or tenant is responsible that such collections are prevented from becoming breeding grounds of anophelines by periodical emptying, or spraying kerosine oil on them. In the case of swampy areas within compounds the owner or tenant is directly responsible that they are not breeding places for anophelines.

In most inland small stations in India the house garden is watered by means of water drawn from a well, usually by bullocks, the water being raised in a leather bag or bullock's skin, or by hand. It then flows into a channel to one or more cisterns from which either minor channels run to the different beds, or the water is carried from them in buckets, pails or garden cans. The bullocks as a rule work only for a few hours in the day so that the cisterns have to be filled for storage of the water for the day. This distribution of cisterns is to economise the labour of the gardener in carrying the water. These small cisterns form one of the commonest breeding places for mosquitoes in all stations and especially in private houses.* *Ps. rossi* larvæ are frequently found in these cisterns and occasionally those of *N. stephensi* also.

When these cisterns are used they should be provided with a well-fitting cover, permitting of access to the water, or they should be emptied once a week and kept empty for several consecutive hours during the daytime, or treated with a mixture of pesterine and kerosine oil twice a week.

In the hot dry season of the year there should be no breeding places in or around houses. At this time all breeding places are artificial, and with a little attention, breeding can readily be prevented. Nevertheless one has seen culicines in such vast numbers at this time as to be a pest.

Pools.—All pools and ponds which cannot be drained should get a layer of kerosine oil, preferably by spraying which avoids waste.

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* Lieut.-Col. G. Gills, I.M.S., *Health and Climate in Hot Countries*, p. 109.

M.—Prophylaxis in the Individual.

Prevention of initial infection is always and everywhere a possibility.—This is now an admitted fact. Such immunity may be secured by defences against the bites of mosquitoes and the prophylactic use of quinine during the malarial season.

Individual prophylaxis may be secured by always sleeping under a mosquito net or in a mosquito-proof room; by protecting all parts of the body from the attacks of mosquitoes in the evening by proper clothes; by protecting the feet and ankles and legs by the use of proper boots (not shoes) or *putties*; protection of the hands and face is less necessary as one can always see or hear mosquitoes making for these parts and hunt them away.

The mosquito net.—The bed should be broad having lots of room between the sleeper and the mosquito net; the sides and ends of the net should be inside the poles, and the lower borders tucked well under the bed, not hanging on the ground. Where poles are not available the net may be suspended from nails in the wall, or, in a tent, by pieces of rope or tape fixed in the tent at points corresponding with similar ones in the top corners of the net. If the bed is not wide, then the lower foot of the net should be lined with some additional cloth; this prevents mosquitoes getting at parts that come into contact with it during sleep. The net should always be well adjusted before going to sleep—it is not always easy to prevent mosquitoes wandering inside the net. The net should be stretched tightly to allow the perflation of air. On getting into bed and fixing the net, the interior should be examined for mosquitoes that may have strayed in, and these captured and killed.

The use of mosquito nets at night, or dwelling in mosquito-proof rooms, may be looked upon as one of the fundamental factors in personal prevention from malarial infection at present; if either is carried out in its integrity, it renders one quite immune from such infection even in the most malarious places. Prophylactic doses of quinine are always advisable in order to secure perfect insusceptibility to infection, especially when not protected by nets or mosquito-proof dwellings.

Where wire-gauze mosquito-proof doors and windows are not provided in private houses, barracks, hospitals, etc., these buildings should be fumigated with sulphurous acid gas (or other culicidal fumigant) every fortnight or so to kill all adult mosquitoes. The methods of carrying out *fumigation* against mosquitoes is fully dealt with in the Section on Culicides (p. 182, *et seq*).

Punkahs and electric fans.—Apart from the fact that when a punkah is pulled by hand the man frequently goes to sleep on duty, mosquitoes will often attack exposed parts even when the punkah is working at full speed. Even when, as is often done, a towel is pinned on to the punkah fringe and its lower edge reaches close to the face, mosquitoes will not be denied their feed of human blood.

The use of electric fans in sufficient proximity to the place where one is working or sleeping is an admirable, efficient, and comfortable protection against attack of mosquitoes.

The use of hand punkahs where mosquitoes are very persistent in the evening is not to be despised, but those who rely on the ordinary punkah being sufficient to ward off mosquitoes run considerable risk of malarial infection.

Quinine prophylaxis.—Foremost amongst all prophylactic measures for the individual in malarial places is the administration of prophylactic doses of quinine during the malarious season. This may be taken in any one of the different ways referred to in pp. 163, 164, which are all applicable to individual prophylaxis. The best way is perhaps one dose of five grains every morning before or with breakfast or on going to bed. supplemented by a ten-grain dose instead of five once a week. In specially malarious localities it is advisable to take ten grains daily; this may be divided into two doses of five grains each. In passing through endemic malarial district all servants should get their daily prophylactic dose of quinine as well as their masters.

After malarial infection has been acquired quinine is the only remedy we possess that will certainly eradicate the parasites. The ordinary prophylactic doses are then insufficient, the quantity reqnired is larger. For the curative treatment of malarial fever by quinine see pp. 159, 160.

Clothes.—It is sitting outside in the evening resting after exercise that mosquitoes buzz round one and attack the ankles, hand, neck and face. In the latter three situations she is often disturbed at her meal and rarely makes much headway. The ankles are a favourite spot and she is readily able to penetrate ordinary socks with her proboscis. Even thick socks are not always protective. They seldom penetrate flannel trousers, but these should not be tucked up below, but arranged so as to completely join the shoes or boots and leave no part of the ankle exposed. The clothes worn by European children in the mornings and evenings are decidedly dangerous as regards mosquito attacks, and call for some modification to prevent malarial infection by anophelines. For little boys the ordinary sailor suit answers the purpose if the trouser legs are worn down to the boots. The clothes of our little girls also seriously require some modification so as to leave no parts of the legs, ankles and arms exposed.

The low-neck evening dress of ladies is decidedly dangerous as it leaves a comparatively large surface exposed for the attacks of anophelines just at the time when the latter are seeking human blood. The evening dress should leave as little as possible of the upper part of the body and neck exposed, and it should not be difficult to devise some form of evening dress which would cover these parts with a light material puffed out in such a manner as to prevent mosquitoes reaching the skin through it.—GILES.

During dinner and at writing tables at night, mosquitoes congregate beneath the tables in the shade to avoid the artificial light. Hence it is well to wear straps below the trousers. With military men at mess (who have the additional advantage of Wellington boots) this is always done, but with mufti evening dress it is very essential. One has lived in a place where ladies wore putties in the evening to protect themselves from the attacks of the thousands of mosquitoes which were always under table at dinner time.

Diet, etc.—Care should be taken to maintain the general health by proper regulation of the diet, bathing, clothing, exercise, etc., and it is important to avoid constipation.

Chills.—Avoid allowing the surface of the body to get chilled. In general terms it may be said that all external conditions that predispose to rheumatism also predispose to malaria.* Proper clothes is a potent agency to protect from chills and mosquito bites. This is specially the case in the evening and at night.

Alcohol.—Alcoholic habits or drinking at all in excess, irregular life, perpetration of hygienic follies, living in insanitary dwellings, all tend to predispose to malarial infection.

In travelling avoid the malarious season if possible.—If travelling through malarious districts and the time of the year can be selected for doing so, the non-malarious season should be chosen, and the travelling should be done during the daytime.

Avoidance of malarious houses.—During the malarial season avoid localities known to be malarious as places of abode, such as proximity to marshes, banks of rivers, and avoid residence adjacent to a native population known to be infected with malaria.

Dak bungalows, etc.—In India, dâk bungalows, rest-houses, and circuit bungalows, are often in the immediate vicinity of villages or towns. A single night spent under these circumstances in a dâk bungalow, etc., may be, and often is, followed by severe malarial fever, if mosquito nets are not used and quinine not taken. In these houses wire-gauze doors and windows are specially indicated.

In case these precautions are impracticable quinine prophylaxis must be followed—five grains daily or fifteen grains twice a week on two consecutive days while in endemic malarial areas.

"By steady and united perseverance in preventive measures on sound lines a great amount of good can be done among natives, and

* The personal PREDISPOSING CAUSES OF MALARIA are detailed in pp. 28–31.

Europeans can secure for themselves an almost entire freedom from malarial fevers."*

N.—Anti-malarial Legislation.

A superfluity of sanitary legislation in this country tends to defeat its own ends, and from ten years' personal experience as health officer of a large municipality, one is convinced that over-legislation in sanitary matters is a mistake. One's general experience was that the inadequacy of the punishments awarded did not act as a deterrent, whilst it involved a considerable loss of time in petty lawsuits for breaches of sanitary regulations.

The actual working of a well-organised anti-malarial campaign should give very little bother to the people, and its beneficial effects would lead to their co-operation

While one is averse to enforcing legislation upon a people who are not educated up to a comprehension of the reason for laws instituted, the anti-malarial sanitarian should have the support of the law in his undertakings. The following would appear to be some of the items upon which legislation is required. Contractors, engineers and builders generally should be forbidden, under penalty, to in any way interfere with the course of natural drainage in their undertakings, and should be prohibited from creating borrow-pits. Where the latter are unavoidable they should invariably be filled up *before the work is relinquished.* All contractors should have a clause in their contract binding them to obey these regulations. Every line of railway and every highway hitherto constructed in this country has been associated with the formation of borrow-pits, of which thousands of miles exist dispersed in all directions. These form one of the general breeding places of anophelines. It would probably be impossible to fill these in now, but what can be done is to roughly canalise them and allow the waters to flow in the direction of the natural drainage. Such a law as that suggested would at least protect the country from the effects of an extension of these borrow-pits.

Other laws required are in connection with collections of water. Water in ponds, pools, basins, public or private places of resort or residence, or in depressions or excavations made for any purpose, should be covered with some protective netting, or drained off at least once a week, or should be covered with some form of petroleum sufficient in quantity to form a thin film over the entire surface twice a week. Municipalities should have the power to treat all stagnant water with petroleum in such a manner as to destroy mosquitoes, where such water is not properly screened or protected. The chief object of anti-malarial sanitation is the destruction of mosquitoes in the aquatic stage of their existence to prevent the dissemination of malaria and other diseases.

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*Practical Methods of Anti-Malarial Sanitation. By Medical Officers of the Duars and Eastern Bengal, *Journal of Tropical Medicine*, 15th December 1908.

Water kept in cisterns, barrels, tanks, earthenware or other utensils for a period longer than one week, should be protected from mosquitoes. Such water containers may be covered with wood, metal or wire-gauze. Buckets containing water for longer than one week such as fire buckets, and other similar containers of stagnant water, should be covered in such a way as to prevent the entrance of mosquitoes, or treated regularly with kerosine and pesterine.

The chief sanitary law required for India is one that would lead to the *abolition of all stagnant surface water.*

With well thought out anti-malarial sanitary legislation, and a proper public spirit, much can be done to lessen the malarial intensity of endemic malarial towns, stations and cantonments.

The sanitary legislation of every province, town and cantonment should contain clauses placing all collections of water in which mosquitoes may breed among the list of nuisances, and giving power to all municipal boards and cantonment sanitary authorities to abate such nuisances.

O.—Education of the Public in Anti-malarial Measures.

Education as an auxiliary to malarial prophylactic measures is of considerable importance. There are comparatively few intelligent men outside the medical profession, who thoroughly understand the rationale of our present-day anti-malarial measures. When the sources of malarial infection, the life-history of malarial parasites in its asexual and sexual phases, its method of communication from man to man through the intervention of anophelines, and the methods of the personal prophylaxis are universally known, much more will be done by individual effort than is now the case. Such knowledge is, in the question of malaria in India, a long stride towards its prevention. We know that if the measures of personal prophylaxis herein advocated were carried out in their integrity, they are completely efficacious. The diffusion of a knowledge of the facts which are connected with epidemiological problems of malaria is essential to the acquisition of the co-operation of all classes in its prevention.

The new facts are to some extent antagonistic to the views handed down in India from time immemorial; many firmly rooted prejudices will have to be eradicated, and the lessons of the new epidemiology of malaria persistently inculcated amongst all classes before we can hope to achieve anything like the success which would follow the adoption of all the anti-malarial measures dealt with in these pages. The universal promulgation of these modern views of malarial prophylaxis is urgently called for.

It is urgently necessary that we should endeavour to inform the public regarding our present-day views as to the nature of malarial parasites and the part anophelines play in the dissemination of malaria.

Medical men and sanitary officials, civil servants, and schoolmasters throughout the country, should make every effort to diffuse this knowledge amongst the less informed classes of the population.

In towns, civil stations, and military cantonments, periodical lectures on malaria and its prevention, and the part played by anophelines in the dissemination of malaria, are useful, serve to maintain interest in the subject and enlist co-operation of the people.

The most difficult part of the task of the practical anti-malarial sanitarian in rural malarious districts is the education of the lower classes regarding the etiology of malaria and its relation to mosquitoes.

One has already stated how it is possible to inculcate the essentials of anti-malarial measures amongst children at school and the rural population. One would aim at instructing village headmen in this respect and allow them to diffuse their knowledge to villagers when they gather together under the village tree in the evening, or to do so in whatever manner they consider best.

In the light of our recent knowledge architects and engineers in this country should studiously consider the various new problems in anti-malarial sanitation It is not intended that these new views should upset all the building traditions in the malarious parts of India ; these cannot be ignored; what is required is the adaptation of new dwellings to the requirements of present-day sanitary principles.

All engineer students in this country should be taught the far-reaching evil effects of creating borrow-pits unnecessarily, and the principles of anti-malarial measures now employed by all civilised Governments should form part of their curriculum of studies.

The following is a simple *leaflet* such as is recommended for universal distribution :—

Causes and Prevention of Malaria.

Malarial fever is due to parasites in the blood. There are two kinds of cells in the blood, red and white. Malarial parasites attack the red cells.

These parasites are carried from man to man by certain kinds of mosquitoes. The two chief kinds of mosquitoes are called *Anophelines* and *Culicines.* Anophelines are the malaria carriers. Anophelines when resting on a wall hold their bodies at an angle to it ; the head, proboscis (the biting mouth parts of a mosquito), and body are in a straight line, and the insect looks like a small thorn stuck slanting in the wall. Culicines rest with their bodies parallel with the wall and appear as if hunchbacked. In anophelines the colour is light or dark brown, in culicines grey, brown, or black with white bands or markings. In anophelines the wings are spotted ; in culicines the wings are plan.

Anophelines, like all mosquitoes, breed in water. In water they lay eggs, the eggs hatch, and larvæ are set free. The eggs of anophelines can only just be seen in water in which they float singly ; the eggs of most culicines occur as little boat-shaped masses, those of others float singly.

The larvæ of anophelines are easily known by their lying flat just under the surface of the water and by their moving backwards in jerks; culicines hang in water head downwards from a long breathing tube, and by their moving forward with a wriggling motion.

About a fortnight after the eggs of anophelines are laid a full-grown mosquito is formed and flies away. If houses or huts are near, they enter and feed on man's blood. If the blood contains malarial parasites these undergo changes in the anopheline, and in about ten days, if they bite a healthy person, that person gets malarial fever.

Anophelines may breed in any collection of water in houses, pools outside houses, in cisterns, drains, tanks, wells, canals, streams, rivers and water channels of all kinds. Hence it is very important to prevent mosquitoes getting at the water in or near houses by keeping water vessels covered, and to prevent water collecting near houses; any unnecessary articles that can hold water, such as old and broken chatties, kerosine oil tins, broken bottles, etc., should be cleared away from houses. Alls pools of stagnant water near houses should be abolished by filling up the holes in which they occur. When pools cannot be filled up, a little kerosine oil (about half a chittack for a square yard of surface) should be thrown on the surface of the water twice a week, this kills all mosquito larvæ. It is wise to try and kill all mosquitoes found in houses.

Quinine kills any malarial parasites that get into the blood A small dose of quinine every day prevents malarial fever altogether. When malarial fever occurs large deses cure it, but to completely kill all the parasites in the blood it is necessary to take a dose daily for three months. Nearly all children have malarial parasites in their blood, and most children have enlargement of the spleen due to these parasites. All children who get malarial fever, and all who have enlargement of the spleen, should be given quinine every day for three months. This will completely cure them of malaria.

During the malarious season every one should take quinine regularly to prevent malarial fever.

P.—Application of the Principles of Mosquito Reduction in Districts, Towns and Military Cantonments.

The essential object of mosquito reduction is to keep down mosquitoes in certain localities so that new infections caused by their number can no longer keep pace with the recoveries, and consequently, malarial fevers will tend to die out. It is carried out by methods which remove the chances of mosquitoes thriving and multiplying. These processes may be embraced under the headings of *minor* and *major works*.

Minor works are such as can be carried out uninterruptedly without the services of a special engineer. They embrace a very large part of the anti-mosquito work of this country, work that can mostly be carried out by mosquito gangs and municipal sanitary establishments generally Such works include the clearing of drains and water channels, draining surface pools, filling up holes, removal of all breeding grounds of mosquitoes around houses, cutting down undergrowth, petrolege of collections of water, etc.

Major works are such as require the aid of a skilled engineer to advise and carry out, and include such undertakings as large drainage works, deepening and filling of large swamps and marshes, canalisation of certain streams, etc. ; these should only be undertaken if urgently necessary and expenditure permits, especially when such drainage, etc., cannot be properly and effectively carried out as minor works; they are specially indicated when the surrounding population is large enough to render such an expenditure justifiable.

For minor works we require *efficient workmen*, who should be constantly employed in towns, villages, military cantonments, jails, and houses; a certain number of *mosquito inspectors* to detect all breeding places and assist generally in the carrying out of minor works. These workmen are formed into mosquito gangs whose duties are detailed below and in the Section on *Prophylaxis of Malaria in Towns*.

The anti-mosquito measures of a district would in this country fall naturally under the Deputy Sanitary Commissioner, and in towns under the Civil Surgeon, unless the town is large enough to maintain its own Health Officer; these officers would advise regarding all major and minor works, and superintend generally the work of an anti-malarial campaign, and draw up an annual malarial report.*

In the carrying out of all such works a certain amount of specific legislation is indispensable ; this is dealt with under a previous Section (pp. 248, 249).

In connection with mosquito reduction in particular localities, one would here quote what RONALD ROSS says on the subject :—

Summary of Objects.—1. We do not propose to exterminate mosquitoes in any entire continent. We propose only to deal with them in the town in which we live and in its suburbs.

2. We do not propose to get rid of every mosquito even in this town. We aim only at reducing the number of the insects as much as possible.

3. We do not think it possible to drain or otherwise treat every breeding place in the town. We aim at dealing with as many as possible.

4. We cannot exclude mosquitoes which may just possibly be blown into the town from miles away. We content ourselves with preventing the insects breeding in the town itself.

Summary of Methods.—1. We start work at once with whatever means we can scrape together.

2. We operate from a centre outward.

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* I am indebted to Prof. RONALD ROSS' *Report on Malaria in the Mauritius* for much that is contained in this Section.

3. We clear houses, backyards and gardens of all rubbish, empty tubs and cisterns containing larvæ, or destroy the larvæ in them by means of oil.

4. We show people how to do these things for themselves, and how to protect tubs and cisterns by means of wire-gauze.

5. When we have cleared as many houses as we determine to deal with, we clear them over and over again.

6. We fill up or drain away all the pools, ditches, old wells, and puddles we can—especially those which contain most larvæ.

7. Such pools as cannot be filled up or drained are deepened and cleared of weeds if they contain larvæ.

8. Streams and water-courses which contain larvæ are " trained ".

9. Where we can do nothing else we destroy larvæ periodically with oil, or by brushing them out with brooms, or by other means.

10. We endeavour to interest our neighbours in the work, and to educate the town into maintaining a special gang of men for the purpose of keeping the streets and gardens absolutely free of stagnant mosquito-bearing water.*

Q.—ORGANISATION OF WORKMEN OF MOSQUITO BRIGADES IN GANGS.

The gangs may range from 3 to 20 in different localities. When in small gangs of three, there should be one headman who gets, say, one rupee a month more pay, all doing the same work, the headman being responsible. In cities and towns gangs of 10 to 15 with one headman will usually be required. *Malis* or gardeners are excellent for this work ; but all agricultural villagers are most useful men in carrying out such works as they have been accustomed to similar operations from childhood. A few of them can readily drain small marshes, rough canalise small irrigation canals, small streams, etc. They are at it constantly in rice-cultivation, draining off excess of water, letting in water into fields, and so on. They are able to clear off in a day small collections of water spread over several hundred square yards of area, or roughly canalise a hundred yards of a stream. The longer such men are employed in the work naturally the more efficient they become.

It is difficult to estimate the total number of gangs required for any particular district; this must be gauged from the local conditions, as the experience of other places is no guide; the best guide is the effects of work done in the district itself. In practically all cases the number of gangs can be reduced after the gross work has been carried out.

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* Prof. RONALD ROSS, *Mosquito Brigades*.

The *minor works* to be carried out in private houses, gardens, etc., can usually be carried out by private servants. The details of the work to be carried out can be gleaned from the list of minor works given previously.

It is necessary to insist that *major works* as anti-mosquito measures should not be undertaken until minor works have failed. An enormous amount of money has been spent unnecessarily in the past on major works due to the incrimination of distant marshes, swamps, and collections of water that had no connection with prevalent malaria

Cantonment barracks, gardens, private houses with large compounds, etc, should be regularly inspected by some responsible officer, and by the mosquito inspector. When there is a Civil Surgeon or Health Officer, he would advise all house owners as to what is actually required.

Mosquito inspectors form a special part of the mosquito brigade. The number required depends on local circumstances. One man can usually do the work of an area of two square miles. His special work is to find out all the breeding places of mosquitoes in his area, and superintend the work of the gangs; he should be thoroughly well instructed, trustworthy, intelligent, able to read and write one vernacular character, and report regularly the work to the officer in charge of the operations. They should be provided with pans or "dippers" for collecting larvæ, and small specimen bottles in a case to bring or send in larvæ they are not familiar with to the Health Officer or Civil Surgeon. As this occupation is not without risk, it will be necessary to allow for 30 to 40 per cent. of these men being infected during the year. The organisation of the mosquito brigades and work of gangs should be carried out under the instructions of the provincial Malarial Officer, Civil Surgeon, or municipalities. With all parts of such an organisation at work at the same time in a malarial area, when malarial diseases are most severe, a profound impression can be made on the prevalence of malaria.

In a campaign against malaria the general distribution of quinine forms an important item.

From the vast importance of malaria in India, it would appear to be necessary that all anti-malarial work in the provinces should be under special medical officers—one such medical officer for each province, and one medical officer acting as head malarial authority, guiding the whole of the anti-malarial work of this country. All these officers should be thoroughly acquainted with malaria in all its phases, including an intimate knowledge of its epidemiology; their whole time should be devoted to the work of organising a general campaign against malaria, examining mosquitoes and other microscopical work; they should have all possible facilities for travelling, and be provided with microscopes and accessories. They should be given liberal powers to act, and the details of the anti-malarial work should be left to them. All officers engaged in anti-malarial work should solicit the interest of influential people in that work One would here mention the work of the Panama Canal Zone carried out under the guidance of Colonel GORGAS, U.S.A., who has entire control over all the anti-malarial measures in operation.

In all cases the whole district or town is to be thoroughly investigated in the manner elsewhere laid down ; maps showing details of the area and marking down all breeding places of mosquitoes ; the working capacities of the different mosquito brigades employed should be thought out ; marshes, streams and other collections of water not managable by minor works will thus become known ; case-reduction will have been effected by additional measures, and when operations have continued for some time, the effects of the measures can be gauged with some degree of accuracy. If after continuing minor measures for a sufficiently long time (it may take one, two or more years to judge of their effects), then, if major works are considered indispensable, and can with advantage be carried out economically, they should be put into the hands of a skilled engineer.

R.—EXPENDITURE ON AND LIMITATIONS OF ANTI-MALARIAL MEASURES.

There are limitations to expenditure in connection with anti-malarial work regarding which we should have definite opinions. Theoretically the limit of expenditure in this connection is the amount that malarial diseases cost the country. Malaria is expensive by reason of the deaths it gives rise to in the population, the loss of labour from malarial fevers in many millions of people (which loss is more manifest in localised collections of labourers working on railway embankments, irrigation canals, various industries such as tea-gardens, factories, etc.), sickness and inefficiency amongst Government employés, including sickness, deaths, and invaliding amongst our officers and troops, etc.

Were it possible to estimate the sickness due to malaria in the provinces in proportion to that due to all other causes, we should be in a position to state how much might be legitimately expended on malaria At present we are unable to gauge this even roughly. In the cases of our army in India, of jails, and asylums, we can with more or less accuracy state that malaria is responsible for about one-fifth of the sickness rate, and this gives one a limit as to the amount of the budget allotment that should be expended on anti-malarial measures. One knows of no records which show that the expenditure on the prophylaxis of malaria has been systematically estimated for.

The expenditure on malaria in this country by the Government of India and the Provincial Governments is limited by the amounts allotted in the medical and sanitary budgets and on periods of epidemics by that of special grants.

Unfortunately measures against malaria must be continued indefinitely, hence all such measures are a permanent drain on the finances of Government and municipalities.

Anti-malarial measures may be classified as *permanent*, that is, carried out once for all and requiring in some cases only occasional repairs; and *annual*, involving a regular expenditure. Amongst the *permanent* measures the most important are drainage works; they also include filling up of extensive pools, ponds, marshes, ditches, pits and excavations generally; rectification of water-courses, etc.

The *annual* measures consist of employing a constant staff of workmen in the form of mosquito brigades or gangs, or some modification of them, to prevent the formation of rain-water pools, the stagnation of water in drains, tubs, gutters and all kinds of vessels; to remove all collections of water that may form breeding grounds for mosquitoes, fill up hollows, borrow-pits and irregularities of the surface, etc. These are referred to under the Sections of *Destruction of Larvæ* and *Prevention of Malaria in Towns.*

In some places the operation of wholesale drainage of marshes, of large collections of water, etc., is practicable, and where this is so the greater difficulty is overcome once for all, as this measure is a radical one; in others, such minor works as can be carried out by mosquito brigades are all that is necessary.

It should be a general principle that before major works are undertaken all possible minor works should be carried out and tried; if they are found to fail, then, if considered indispensably necessary, major works may be put in hand.

The anti-malarial sanitarian knows that public funds are limited, and his aim will be to adopt measures which can be relied on to give the best results with the least expenditure of funds He fully recognises that all anti-malarial measures must necessarily be modified by local conditions.

Whilst all anti-malarial measures are expensive, the cost is directly and indirectly recovered by the actual saving of lives, reduction of sickness and increase of the number of working men, and by reduction of invaliding, hospital accommodation, medical attendance, etc., In reducing anophelines we likewise reduce other kinds of mosquitoes, such as the *C. fatigans*, which transmits filariasis and possibly other diseases, and thus we simultaneously lessen the various morbid conditions associated with filariasis. Anti-mosquito measures have the effect also of improving the general sanitation of places in which they are carried out.

In a generalised anti-malarial campaign we have to consider the classes of people to be dealt with and their intelligence; whether the land is cultivated or uncultivated, and whether it is rural or urban;

whether our measures are for a sea coast, city or town, inland or for villages; the amount of rainfall, and seasons of greatest falls; the nature of the seasons, whether there is a hot dry summer and a cold winter, or a more or less uniform climate throughout the year; whether the area is flat, high, low, forested or covered with crops of sugarcane, rice, or other cereals, and the manner in which such crops are irrigated. We take into account the nature of the soil, the slope of the ground, nature of all existing jheels and marshes, character of the natural drainage of the country around and of the artificial drainage in existence in the district or town, the degree to which existing sanitary establishments can help in anti-malarial operations, etc.

It is often a question in malarial places as to where the sanitary officer should begin anti-malarial operations first. The answer is to commence with those measures which can be at once adopted, and these are as a rule found to be the least expensive. Neglect of this rule leads to numerous disappointments. It is useless to begin by, say, attempting to drain large marshes, lowering the subsoil water level of a whole district by large drainage schemes, etc.

In all cases it is indispensably necessary to have an accurate estimate as to the prevalence of malaria in the district and the factors contributing to this prevalence before fixing on any method.

In every locality the question of the cost has to be seriously considered. The anti-malarial sanitarian asks himself whether the place can afford to pay the cost of the best possible prophylactic measures adoptable, and, if not, he works out the best measures available, within the means of the place.

As far as we can at present judge it is unfortunately the fact that the advantages to be got by *anti-mosquito measures in rural districts are comparatively limited.* It is of little value to drain a large marsh because there are a few huts on its banks; or to extend anti-mosquito measures round a single house to the extent of the mosquito range in the neighbourhood and beyond. Mosquito reduction is specially for cities and towns; it is applicable in a limited sense only to villages. For *single separate houses* mosquito-proof doors and windows, or mosquito nets, supplemented by quinine prophylaxis, and the treatment of all small collections of water in the vicinity by drainage, rough canalisation, or kerosine oil, are specially called for. In the case of small towns and villages situated in the midst of extensive marshes, marshy forests, flat, water-logged country, the cost of mosquito reduction will often be too great. Such a conclusion should not, however, be arrived at without full consideration of the local circumstances and, if necessary, a preliminary trial on a small scale. The removal of the smaller immediate breeding places costs little and may do much good. In villages this removal would cost nothing as it would be carried out by the villagers themselves. If this fail other measures are still open. These remarks apply to very extensive districts in this country including many of the large tea-gardens in Assam and numerous industrial works.

In a general anti-malarial and anti-mosquito campaign in India we have at the commencement only general principles to guide us. The measures applicable to one place are seldom suitable to another. Each district and each station has to be considered separately, and the advantages and disadvantages of each recommendation fully considered before it is made. The adoption of methods that are specially applicable to particular localities are soundest and safest.

Anti-malarial campaigns in malarious districts should be as generalised as possible; mere local campaigns (except in the case of towns, cantonments, and their immediate surroundings in such districts) are of little permanent use; such campaigns should be carried out generally, simultaneously and vigorously throughout the area it is intended to influence; the campaign should be commenced in September or October; this is the best time also to make examinations of the spleen and blood to estimate the amount of malaria or the degree of improvement from previous anti-malarial measures; and for universal distribution of quinine. Mosquito brigades should be located in their areas and given their allotted tasks. Civil Surgeons and district sanitary officers should give all the assistance they can in the work. There should be a special continuous policy to reduce malaria throughout the country, and the more such a policy is maintained by Government the more benefit will be derived from anti-malarial measures. The enthusiasm, skill and efforts of single experts may do much good in limited areas, but without the influence of Government over the whole country, and a well defined and persistent policy for prophylaxis, success is not likely to be continuous or widespread. Wherever anti-malarial measures are in operation under Government or municipalities, an annual report showing the results should be prepared. The annual malarial report should contain a tabular statement giving the details of the present year and past years for comparison, including the number of malarial fevers, their varieties in age-groups, an account of the work done, expenditure, the results, and the work still required to be done. In the case of children the report should show average total children, children with enlarged spleens, children treated with quinine, and the averages for four quarterly periods of the year.

We require a real solid effort to definitely measure the amount of malaria in all districts of this country. At the present moment we are unable to guess within many millions the actual number of persons who suffer from malaria annually. This measurement of malaria should be repeatedly carried out to ascertain whether the anti-malarial measures put into operation are doing good. This gives the local authorities a basis to work on, and may indicate the directions in which modifications of the methods initiated may be called for. Without knowing the effect of measures on malaria we cannot gauge the degree of benefit, if any, accruing, and it is certain that if no beneficial effects are published, works involving expenditure will be stopped.

The more one's experience grows in dealing with malaria prophylactically, the more it becomes evident that one of the most predominating causes of ill-health is the general want of knowledge of modern scientific teaching as to the part played by mosquitoes in the propagation of malarial infection. One has repeatedly heard the view of the dissemination of malaria through anophelines ridiculed by intelligent officials of Government in various departments.

Present prophylactic measures are sound.—One has no hesitation in stating that our present recognised methods of protection against malaria are scientifically sound, although in many places, difficult to apply. In the public prophylaxis of malaria we should avoid councils of perfection, *e.g.*, large drainage schemes, insisting on the isolation of all cases of malarial fever, wire-gauze netting for doors and windows, universal cinchonisation of the population, etc., in all places indiscriminately; it is our duty to endeavour to do as much as possible in each direction; we should employ as many of the known prophylactic measures as are practicable in the localities concerned, for we know that every individual success has its influence for good. The best anti-malarial results so far have been obtained in places where all prophylactic measures have been put into operation more or less simultaneously, and continued over a long period. This, however, has always been found to be somewhat costly. All public prophylactic measures against malaria necessitate the expenditure of money, sometimes large sums being required, they always mean a great deal of work as well as some knowledge of general hygiene. Some anti-mosquito campaigns have erred in dealing first with large or extensive and difficult projects instead of the cheaper and easier ones. One of the most usual causes of failure of anti-malarial measures is that of endeavouring by one public health measure to eradicate malaria, and its abandonment after it has been found to fail.

The average malarial intensity of a locality depends on many factors, such as the endemic index, sporozoite rate, extent to which individual prophylaxis is practised, etc., so that the cause of failure may not be always easy to ascertain. To ged rid of malaria in any particular locality by artificial means may take several years; this is the usual experience of the limited number of instances in which it has been achieved.

No system of prophylaxis covers all places.—It is impossible to give the details of the measures to be adopted in all cases—these have to be determined by local circumstances; in some places all measures may be adopted, in others only a few are possible. In intensely malarial areas, in many cases, do all we may and malaria is not mitigated. In Italy the chief anti-malarial measures adopted have been—drainage, agricultural improvement, prophylactic administration of quinine, and mechanical protection against mosquitoes. There are certain regions, such as the valleys of our large rivers in India, Burma and Assam, where breeding grounds for anopheline larvæ are almost universal; others in proximity to extensively irrigated lands under rice cultivation; in such places anti-mosquito measures must be of limited use in the depopulation of these insects.

Chief factors interfering with malarial prophylaxis.—The chief factors militating against the operation of malarial prophylaxis in localised areas are—indifference of the people, callousness of municipalities, and possibly want of enthusiasm on the part of local authorities generally. All familiar with the labours connected with such prophylaxis must allow that it is always a heavy task to guide the eradication of malaria.

It is unfortunately the fact that in some places, while anti-malarial measures were actually in operation, the average number of cases of malarial fever increased, but this is no ground for despairing of success. There are in such cases some undiscovered factor or factors militating against the success of such measures. We are, of course, only too conscious that there are still many problems connected with the epidemiology of malaria to be solved; the trend of anti-malarial investigation is towards the solution of these problems. We have certain definite general principles to base our prophylactic measures on, and we should pursue our campaign on these principles.

It is a curious fact that anti-malarial operations which are recorded as successful in our medical journals are in the great majority of cases quoted by writers as such, whilst those that are published as failures are subjected to severe criticism. There is no country in the world in which more anti-malarial and anti-mosquito measures are in operation than in India. In every military cantonment and civil station, local conditions fostering malaria are to some extent being inquired into and breeding places of anophelines sought out and reduced more or less. That no serious impression is being made on the malarial rate in these places is due to an absence of concentrated effort, and of universal co-operation in the measures, but specially to the absence of funds necessary to make these measures radically useful.

When we review the present position of our knowledge with regard to the epidemiology of malaria as compared with that of, say, 30 years ago, we fully recognise the great strides that have been made. Nevertheless we are compelled to admit there are still many important points awaiting solution. One of the great gaps is connected with the habits of anophelines. From the very nature of the difficulties connected with a comprehensive knowledge of the habits of anophelines, the time occupied in such studies, the seeming paradox of their co-existence with malaria cases and comparatively little endemic malaria, the occurrence of widespread malaria with few anophelines, and with few apparent breeding grounds, and other intricate problems—we are forced to conclude that we are remote from the time when in India we can hope for a disappearance of endemic malaria. It is unfortunately true that we are as yet *unable to estimate the real intrinsic values of the factors* connected with malaria with which *we are* acquainted, and it is equally true that there are certain factors connected with the epidemiology of malaria with which we are as yet totally unacquainted.

An enormous amount of laborious work has to be undertaken before we can solve some of the more important points connected with the epidemiology of malaria; much of this work must of necessity be carried on in the endemic areas of malaria, and it will consist of observations made on the peculiarities connected with the habits of all malaria-carrying anophelines, their breeding places, methods of hibernation and æstivation, the existence or not of more than three forms of malarial parasites in India, the pathogenesis of relapses, the phases of malarial parasites in the human economy during latent infection, etc.

Whilst there are these gaps in our knowledge of the physiographical and etiological relations, pathological anatomy, and pathogenesis of malaria, it may be stated that there is no widespread infectious disease of man regarding which our knowledge is so complete; and by far the greatest part of this knowledge has been acquired during the last 30 years, this is, since the discovery of plasmodia of malaria by LAVERAN in November, 1880, and the mosquito cycle of malaria by RONALD ROSS in 1897. The work of RONALD ROSS in connection with the elucidation of the main epidemiological fact in malaria is the greatest scientific discovery ever made in this country.

APPENDIX.

MALARIAL TOXIN.

In dealing with the *Pathogenesis of Malarial Fevers* one referred to the existence of malarial toxin or toxins as highly probable (p. 108). The reasons for this assumption were the analogy of malarial fevers with other infectious diseases, the fact that a certain degree of relative immunity eventually follows repeated attacks of malarial fevers, the fact that it is almost certain that anti-toxins are formed in the blood during malarial paroxysms,* the relation of the pyrexial phenomena of a malarial paroxysm to the sporulation of malarial parasites, the fact that the degree of anæmia produced is altogether disproportionate to the actual number of red cells invaded by malarial plasmodia, the degenerative changes in the internal organs, such as the spleen, liver, kidneys and brain, cannot be accounted for in any other way, the occasional occurrence of coma during malarial paroxysms in the absence of malarial parasites or malarial pigment in the brain, the proved increased toxicity of the urine, and probably increased toxicity of the sweat, and for other reasons of less significance.

Notwithstandiug the importance of the subject, the actual experimental work in connection with malarial toxin has been comparatively meagre. One has shown that the experiments of MANNABERG and CELLI were practically negative; those of MONTESANO and GUALDI are equally so.

Positive and convincing experiments regarding the existence of a malarial toxin have been carried out by ROSENAU, PARKER, FRANCIS and BEYER, of the Yellow Fever Institute.† These experiments show that there is in malarial blood during the first and second stages of the paroxysm, that is, before the temperature begins to fall, a toxin which is manufactured by malarial parasites, and that this toxin is responsible for all the phenomena of a malarial paroxysm. The methods by which these authorities proved the existence of this toxin were based on the experiments carried out by REED, CARROL, AGRAMONTE and GUITERAS of the United States Commission, and MARCHOUX and SIMOND of the French Commission, to prove that the germ or poison of yellow fever is contained in the blood of patients suffering from that disease. These experiments consisted in injecting into the veins malarial blood, abstracted from cases of malarial fever at differeut stages of the malarial paroxysm, the blood being defibrinated and in some filtered through a Berkefeld or a Pasteur-Chamberland filter, in others unfiltered.

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* FORD, *Medical Record*, Vol. LXVI, p. 1001.

† *Experimental Studies in Yellow Fever and Malaria.*

The first experiment was carried out through a man, Andrez Mendez, 39 years old, who, during the preceding three years in Vera Cruz had suffered from several attacks of fever, and at the time of the observations had been suffering from recurrent attacks of fever for about a month, which came on every other day. The man was physically robust, but very anæmic, the mucous membranes being particularly pale, and the skin cold and damp.

About noon on the 6th November, he was seized with a chill. By 12-30 P.M., the rigor was very marked and he was shaking violently; he could not hold the thermometer in his mouth and the pulse was taken with difficulty. The temperature was rising rapidly, it being at the time 39·1° C. At 12-40 P.M., blood was drawn from one of the superficial veins at the bend of the elbow. The blood flowed freely; 125 cc. were quickly drawn. It was permitted to flow into a porcelain dish and defibrinated by whipping with sterilised forks. Clotting took place very quickly, so that the fibrin was readily and rapidly separated from the fluid.

Judging from the size of the clot and colour, the fibrin had enclosed a number of corpuscles. The defibrinated blood showed no further tendency to clot, and on microscopical examination looked like fresh blood containing a normal number of corpuscles.

To 25 cc. of defibrinated blood was added 25 cc. of physiological salt solution, and this diluted blood was filtered through a Berkefeld filter.

Nine cc. of the filtrate were injected into the right basilic vein of Louis Peredo. This injection took place at 1-40 P.M. Stained smears of the filtrate showed no morphological elements. The filtrate had a distinct red colour. As a control, Jose Ojeira, at 2 P.M., was given an injection into his left basilic vein of 4 cc. of the unfiltered mixture. As the blood was diluted with equal parts of salt solution, he, therefore, received 2 cc. of Mendez's blood.

The unfiltered mixture of defibrinated blood and salt solution, upon microscopical examination shortly after Ojeira received his injection, showed amœboid tertian organisms with dancing pigment.

After drawing the blood from Mendez he continued to have a chill with a severe rigor and chattering of the teeth, accompanied by nausea and vomiting. His temperature continued to rise after the blood was drawn until it reached 40·2° C. The febrile period was followed by drowsiness and moisture of the skin.

Mendez was kept under observation without quinine, and had another typical malarial paroxysm the next day. All the evidence in his peripheral blood, which was examined frequently, pointed to a severe double infection with the tertian parasite. He was then given quinine which entirely controlled the disease and caused the complete disappearance of the parasite from his peripheral blood.

The results caused by the injection of the blood of Andres Mendez into Peredo and Ojeira follows :

Louis Peredo, aged 25 years, was thoroughly examined on the 26th August, and found to be physically sound ; the blood contained no malarial plasmodia ; the urine was normal. From the 28th August he was kept constantly in a mosquito-proof room. On October 27th, after having been under daily obvservation for two months, during which time he remained in normal health, he was injected with the filtered blood of Filomena Martinez, who at the time was suffering with a paroxysm of malarial fever of the æstivo-autumnal type, his blood containing many young ring-forms and crescents. The blood was drawn from Martinez during the time of the decline of the paroxysm. It was then allowed to clot in the ice-chest, the clear serum was pipetted off and diluted with an equal quantity of isotonic salt solution, and this filtered through a new Berkefeld filter. Twenty cc. of the filtrate, which on account of the solution represented 10 cc. of the blood serum, were injected into the left median basilic vein of Peredo.

Peredo was carefully watched from the hour he was injected, but he remained in good health, and no deviation from the normal was detected. His temperature was taken every four hours during the night and day, both before and following the injection. No symptons developed. His blood was examined daily for plasmodia, but none were found. The result of this injection must, therefore, be considered negative.

Ten days later he was again injected with filtered malarial blood under different circumstances and with positive results.

At 1-40 P.M., 6th November, he was given an intravenous injection of the blood of Andres Mendez, passed through the same Berkfeld filter as before. Mendez was suffering from a double tertian infection, his blood was drawn during his chill and before the height of the paroxysm. Thinking that allowing the blood to clot four or five hours in the ice-chest in order to get clear serum for filtration might be too severe a tax on the vitality of the malarial parasite, the blood was this time defibrinated, diluted as before with an equal volume of physiological salt solution, and filtered through the same Berkefeld filter in the same manner as was done with the blood of Martinez. Nine cc. of the filtrate were injected into the basilic vein of Louis Peredo. This injection took place at 1-40 P.M.

About 35 minutes after receiving the injection he began having chilly sensations and headache, and presently went to bed (2-25 P.M.). Five minutes later he was having a violent chill and his teeth chattered. The face was pale, and at this time he vomited part of the dinner he had eaten a short time before receiving the injection. The patient complained of headache, felt cold and had pains in the knees. The skin was dry. The chill lasted half an hour.

At 3 P.M. he had a slight rigor.

At 3-15 P.M. he felt " warm inside," and all sense of chilliness had disappeared, but he still had headache.

At 3-25 P.M. he had severe pains in the legs.

At 3-30 P.M. he vomited the remainder of his dinner.

His temperature was rapidly rising and at 4 P.M., and just 2 hours 20 minutes after the injection, it reached its highest point (38·7° C.).

The pains in the knees and back continued, and nausea and vomiting now became a prominent feature of the paroxysm.

The fever gradually subsided and reached normal at 4-30 next morning.

As the fever subsided the skin became moist, the nausea and pains gradually disappeared, so that by 6 P.M. the patient was quiet and dozing. The entire paroxysm lasted eight hours.

Peredo had what appeared to be a typical malarial paroxysm, beginning with a distinct rigor associated with a rise of temperature and followed by slight sweating. His paroxysm, so far as symptoms were concerned, was very similar to the paroxysm from which Andrews Mendez suffered, especially the nausea and vomiting.

Peredo was kept under very close scrutiny until 24th November, that is, 18 days following the injection, during which time he remained quite normal and no plasmodia could be seen in his peripheral blood.

Jose Ojeira, 18 years old, who stated that he had never had fever of any kind, was examined on the 11th August, and found to be physically sound, of robust physique; there were no malarial parasites in his blood and the urine was normal.

On August 13th he was transferred to a mosquito-proof room in the laboratory, where he was kept under close observation.

On the 27th October, at 7 P.M., he received, intravenously, 20 cc. of diluted blood serum from Filomena Martinez (æstivo-autumnal infection), passed through a Pasteur-Chamberland filter B. This represented 10 cc. of blood serum.

Ojeira showed no symptoms whatever as a result of this injection.

The blood of Martinez was drawn after the height of the paroxysm and while the temperature was on the decline. Martinez was suffering with a severe æstivo-autumnal infectiou at the time the blood was taken.

Ojeira's blood was examined several times daily, both before and following this experiment, and at no time was anything resembling a malarial parasite seen in his peripheral blood.

On the 6th November, the patient having continued in good health since the last experiment, was used as a control for the experiment on Peredo. At 2 P.M. on this date he was given an intravenous injection of 4 cc. of the unfiltered, diluted, and defibrinated blood of Andres Mendez. At the time the blood was drawn from Mendez it contained a heavy infection of double tertian malaria, and the blood was taken from him during a chill and before the height of his paroxysm. It was at once defibrinated, diluted with an equal volume of physiological salt solution, and filtered through a Berkefeld filter. Nine cc. of the filtrate were given intravenously to Peredo, causing a malarial paroxysm without, however, the presence of the malarial parasite, and everything pointed to its having been due to the toxin in the blood of Mendez.

Ojeira, who received 2 cc. of unfiltered blood (4 cc. diluted), reacted within an hour, with a slight rise of temperature and nausea, and four days later, developed a typical malarial paroxysm, with many tertian parasites in the peripheral blood.

"There can be no doubt that the reaction to the 2 cc. of defibrinated blood injection into the vein of Ojeira caused a slight paroxysm, which it is reasonable to suppose was due to the same poison present in the blood of Mendez, and which also caused the reaction in Peredo.

"It will be noticed that 2 cc. of this blood caused but a slight reaction in the case of Ojeira, while 4·5 cc. caused a more marked reaction, with a rise of temperature to 38·7° C. in the case of Peredo, indicating in a very definite manner that the severity of the symptoms were directly due to the quantity of the poison introduced. Ojeira did not have a chill or other manifestations of a malarial paroxysm other than a rise of temperature and nausea. He vomited gastric mucus several times.

"On November 10th, the 4th day following the injection, Ojeira had a typical malarial paroxysm, with tertian parasites in his peripheral blood. He suffered with a double infection, having a chill every day. The character of the parasites in his blood and the clinical course of the disease resembled in all respects those of Mendez, from whom the blood was taken. Both cases were entirely controlled by quinine."

These experiments, which the records show were conducted with all possible scientific care and precision, leave no doubt in the mind as to the existence in the blood of a pyrogenetic toxin during the early stage of a malarial paroxysm, and the inference is strong that this toxin is liberated from the red blood cells at the time the spores are set free. It is also highly probable that the toxin is soluble in the plasma of the blood, and continues in solution in the serum after this has been separated from the plasma and blood corpuscles. It would seem that the malarial toxin, after disturbing the thermotaxic mechanism by increasing thermogenesis and lessening thermolysis, is either eliminated, or its effects neutralised by an antitoxin generated in the blood.

At the initial stage of each malarial paroxysm a fresh quantity of toxin is liberated into the plasma and the whole of the phenomena of a paroxysm commenced.

It is almost certain also that the malarial toxin is responsible for at least part of the degenerative changes met with in the parenchymatous cells of the spleen, liver, kidneys and brain in cases of lasting malarial infection

So far as one can ascertain the highly interesting experiments referred to above have not been repeated. There are unrivalled facilities for conducting such experiments in this country, and one takes this opportunity of suggesting that the work of Rosenau, Parker, Francis and Beyer be repeated in one or other of the bacteriological laboratories of this country. With the aid of an expert scientific chemist in such an enquiry, it is highly probable that the actual toxin or toxins of malarial blood would be isolated. Simultaneously the nature of the antitoxin of malarial blood could be enquired into, and Ford's work, previously referred to, re-investigated.

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