

(NEW SERIES.)

No. 56.

SCIENTIFIC MEMOIRS  
BY  
OFFICERS OF THE MEDICAL AND SANITARY DEPARTMENTS  
OF THE  
GOVERNMENT OF INDIA

---

MALARIA IN THE ANDAMANS

BY

MAJOR S. R. CHRISTOPHERS, M.B., I.M.S.

*Assistant to the Director, Central Research Institute, Kasauli*

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ISSUED UNDER THE AUTHORITY OF THE GOVERNMENT OF INDIA BY THE  
DIRECTOR-GENERAL, INDIA MEDICAL SERVICE



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# Malaria in the Andamans.

## I.—Introduction.

THE Andaman Islands are situated in the Bay of Bengal two hundred miles from the nearest point of the mainland of Burma. They consist of three large islands and a multitude of smaller ones, the total area being about 4,000 square miles.

At the south end of the southern Island is the convict settlement of Port Blair, a small area of not above twenty miles in longest diameter, which is from our present point of view the Andamans. Beyond the confines of the settlement the whole land, hill and valley alike, is trackless forest.

An important feature in these islands is the evidence of isolation shewn by the flora and fauna. With the exception of wild pig there are no indigenous large mammals. There are no crocodiles in the swamps and rivers, and though the country is clothed in forest there are no monkeys. The question of what species of *anopheles* occur in these islands is therefore one of considerable interest.

The aborigines are of an extremely primitive type resembling the Bushmen of Africa and are quite unlike any existing neighbouring race. They lead a nomadic life, do not till the ground and are so few in number, being estimated at under 2,000 for the whole Andaman group, that they cannot be considered as forming a population in the ordinary sense. With the exception of a few who are supported by Government at the Andamanese Home at Port Blair these primitive and hostile people are rarely or never seen.

Around the settlement for a distance of about ten miles the country has been partially cleared. The most conspicuous feature of this area is a long ramifying inlet of the sea, the harbour of Port Blair, around the shores of which the various stations and villages of the Settlement are situated. The country consists of low forest clad or partially cleared hills between which lie long flat swampy valleys or the ramifying arms of the harbour and its tidal mangrove swamps. Wherever possible portions of these tidal swamps have been reclaimed and they then form the characteristic *salt swamps* of the locality. Near the embankment which protects them these swamps are liable to be flooded at high tide and there are stretches of mud and open water. Further inland they are covered with a growth of coarse grass or some form of undergrowth and are planted with cocconut palms from the cultivation of which is

derived a considerable revenue. The extent and general characters of these salt swamp lands will be gathered from the map of the settlement and the photograph accompanying this report.

Behind the salt swamp and in almost every valley there are in addition extensive fresh water swamps sometimes entirely, at other times partially, converted into paddy land.

On the hill slopes are small mountain streams and an abundance of swampy patches and small pools. Even the tops of hills during the wet season are more or less waterlogged and pools are everywhere present.

2. The few partly civilised Andamanese within the settlement, at most a few score, are supported by Government and live in an isolated position in the Andamanese Home. They in no way influence conditions as regards transmission of malaria among the convicts. Apart from these few aboriginals the population of the settlement is entirely an immigrant one and is restricted to the convicts and those whose work is connected with them.

The convicts are of two classes, the *labouring convicts* still under modified prison discipline, and *self-supporters* who are ticket-of-leave convicts, allowed, with certain restrictions, to lead a free life on the Island.

The former, numbering from 10,000 to 12,000, are housed in large barracks, the various collections of which form the so-called stations of the settlement. These barracks are located at various points around the harbour and for the most part are built on elevated sites, often high bluffs overlooking the sea, which have been chosen with a view to health.

The *self-supporters* numbering about 2,000 live in villages which, owing to the necessities of rice cultivation, are scattered more widely over the settlement and are often situated several miles from the shores of the harbour. Some villages, like the stations, are on the tops of low hills, but many are in low-lying situations close to paddy land or swamp.

Besides the self-supporters there are about 2,000 *free residents* either time-expired convicts or the offspring of convicts. These live a life very like that of the self-supporters in the area to the south of the harbour (Eastern District).

3. It is among the labouring convicts, judging from the statistics, that malaria is most prevalent. Also it is among the labouring convicts, more directly under the care of the medical authorities, that we especially wish to ascertain the conditions in regard to malaria. But for several reasons the labouring convicts do not form a very suitable community for determining the facts regarding malaria transmission. Above all the fact that they are liable to frequent movement from one station to another interferes with investigation on this point.

The villages of the self-supporters, where there are a certain number of

children, all or nearly all born on the spot, and where the whole population is a fixed one, are on the other hand eminently suitable for our purpose. Hence the question of the prevalence and distribution of malaria in these villages will first engage our attention, the more complicated question of infection among the labouring convicts being postponed until we are in a better position to understand the general principles underlying the transmission of malaria in this particular locality.

## II.—Malaria in the villages.

4. The results obtained from an examination of children and adults in the villages are given in Table I. So far as possible all the children in the settlement were examined and though the number living in some of the villages was small it is possible to draw some very definite and important conclusions regarding the natural history of malaria in the Andamans.

TABLE I.

	SPLEEN RATE, CHILDREN.			PARASITE RATE, CHILDREN.			SPLEEN RATE, ADULTS.			PARASITE RATE, ADULTS.		
	Children examined.	Number with enlarged spleen.	Spleen rate.	Children examined.	Number with parasites.	Parasite rate.	Persons examined.	Number with enlarged spleen.	Spleen rate.	Persons examined.	Number with parasites.	Parasite rate.
Villages close to the sea —												
Female Jail . . . .	30	7	...	—	—	...	—	—	...	—	—	...
Bindraban . . . .	9	5	...	8	2	...	—	—	...	—	—	...
Bamboo Flat . . . .	16	4	...	16	2	...	22	4	...	—	—	...
Kadakachang . . . .	3	3	...	...	...	...	24	4	...	—	—	...
Ogra Baraij . . . .	15	4	...	15	4	...	9	1	...	—	—	...
Port Mouat . . . .	12	7	...	11	4	...	33	7	...	32	0	...
Shouldari . . . .	8	2	...	—	—	...	—	—	...	—	—	...
Baighalsingpura . . . .	7	0	...	7	0	...	24	3	...	17	0	...
Dhani Khari . . . .	4	0	...	4	1	...	28	6	...	—	—	...
	104	32	32	61	13	21	145	25	17	49	0	0

TABLE I—contd.

	SPLEEN RATE, CHILDREN.			PARASITE RATE, CHILDREN.			SPLEEN RATE, ADULTS.			PARASITE RATE, ADULTS.		
	Children examined.	Number with en- larged spleen.	Spleen rate.	Children examined.	Number with para- sites.	Parasite rate.	Persons examined.	Number with en- larged spleen.	Spleen rate.	Persons examined.	Number with para- sites.	Parasite rate.
Villages some part of which approaches the sea—												
Phœnix Bay . . . . .	10	2	...	—	—	...	—	—	...	—	—	...
Aberdeen . . . . .	90	4	...	—	—	...	—	—	...	—	—	...
Jungly Ghat . . . . .	15	1	...	—	—	...	—	—	...	—	—	...
Lamba Lines . . . . .	20	3	...	—	—	...	—	—	...	—	—	...
Stewartganj . . . . .	11	1	...	11	0	...	—	—	...	—	—	...
Mitha Khari . . . . .	12	2	...	11	2	...	11	3	...	—	—	...
Namanagahr . . . . .	16	2	...	16	2	...	12	0	...	12	0	...
Maymyo . . . . .	—	—	...	—	—	...	31	8	...	19	0	...
	174	15	9	38	4	10	57	11	19	31	0	0
Inland villages—												
Wimberleyganj . . . . .	16	0	...	—	—	...	52	0	...	...	...	...
Cadellganj . . . . .	2	0	...	—	—	...	—	—	...	...	...	...
Anikhet . . . . .	17	0	...	17	0	...	—	—	...	...	...	...
Tusanabad . . . . .	32	0	...	32	0	...	41	1	...	...	...	...
Hobdaypur . . . . .	16	2	...	—	—	...	—	—	...	...	...	...
Manpur . . . . .	4	0	...	—	—	...	—	—	...	...	...	...
Templeganj . . . . .	9	0	...	—	—	...	—	—	...	...	...	...
School Lines . . . . .	30	0	...	—	—	...	—	—	...	...	...	...
Pahargaon . . . . .	22	0	...	—	—	...	—	—	...	...	...	...
Austenabad . . . . .	22	0	...	—	—	...	—	—	...	...	...	...
Protheropur . . . . .	19	0	...	—	—	...	—	—	...	...	...	...
Guaracharama . . . . .	42	0	...	—	—	...	—	—	...	...	...	...
Hompheyganj . . . . .	7	0	...	—	—	...	—	—	...	...	...	...
Nowshera . . . . .	6	0	...	6	0	...	—	—	...	...	...	...
	244	2	2	55	0	0	121	1	1	...	...	...
Small island without ano- pheles.												
Ross . . . . .	57	1*	0	...	...	...	...	...	...	...	...	...

\* Re cent arrival.

The most severely affected village was that of Port Mouat. This shewed a spleen rate of about 60 per cent. and a parasite rate of about 30 per cent. The station close beside the village also has the reputation of being the most malarious in the Settlement. The villages of Bindraban and Kadakachang also shewed a high degree of infection. The situation of these villages is shewn in the map of the Settlement accompanying this report. None of the other villages could be considered as shewing hyperendemic conditions.

The villages of Ogra Basaij, Shouldari and Bamboo Flat gave spleen rates of about 25 per cent. These villages like those already mentioned are situated close to the coast or to salt swamps that in certain places stretch a considerable distance inland.

Many villages shewed still lower rates. In some of these infection was limited to some particular portion of the village so that if this were excluded the rate was 0 per cent. In the large village of Aberdeen it was only in an outlying group of houses bordering upon the sea that any enlarged spleens occurred. The village of Lamba Lines is another example where the children were negative with the exception of one family living in a house at the extreme end of the village nearest the sea.

With one exception (Hobdaypur) all the villages lying inland from the shores of the harbour shewed no indication at all of malaria. Unfortunately Hobdaypur was not visited as the children had come to a neighbouring village to be examined, and it is possible that Hobdaypur was not so far from the influence of salt water as would seem to be the case from the map. Unfortunately also the history of the two affected children (length of residence at Hobdaypur, etc.) was not ascertained.

With this possible exception, to which too much weight cannot be attached, not a single case of enlarged spleen occurred in an inland village.

Some of these inland villages are well situated on spurs of hills and it was thought at first that their situation accounted for their freedom from malaria. But as observations were extended it was found that a number of inland villages, notably those to the south of the harbour, were situated on very low-lying ground, in some cases on the very edge of swamps (fresh water), and that these were likewise free from malaria.

The village of Guaracharama, where the examination of 42 children failed to shew any case of enlargement of the spleen, was situated in the midst of low-lying ricefields. Lamba Lines lies along the margin of a large swamp much shot over for snipe and is at the same time close to a heavy growth of jungle. School lines, Austenabad, Protheropur and Manpur are all in situations that one would have expected to be very malarious. Even the altitude of those villages situated on spurs, a few hundred feet at most, was not sufficient in an ordinary way to have been any protection.

The village of Aberdeen is situated on low hills about 50 feet above sea level surrounded and intersected by flat fresh-water swamp and paddy land. A large area of deadly looking uncultivated swamp full of pools penetrates even among the houses and lies only a stone's throw from many of them. It was a great surprise under the circumstances to find that none of the children shewed enlargement of the spleen. In the outlying portion previously referred to, two families were found living close together in which four children were found suffering from enlargement of the spleen. At the time this sporadic incidence of malaria could not be explained. Later on, when the relation of malaria to *Nsm. ludlowi* and salt swamp was ascertained, the explanation was quite simple. These houses were the nearest to an extensive source of *Nsm. ludlowi*.

5. A number of the most malarious villages were completely shaded by *Pithecolobium* trees planted when the villages were first laid out and it was thought that this condition might be a factor responsible for an enhanced malaria rate. But it was not difficult to find healthy villages similarly shaded, e.g., Tusanabad.

Again porosity of the soil was considered as a possible factor. But Port Mouat, the most affected of all the villages, was situated on more than usually porous soil and no definite connection in other cases could be traced.

Some of the villages were older than others, and in some more cattle were kept, a condition which experience has shewn favours anopheles. But neither of these circumstances served to explain the different degrees of prevalence of malaria.

The one circumstance which appeared to determine the amount of malaria in a village was propinquity to the sea coast. Considering the circumstances of the different villages it was possible to say that malaria was confined to villages within a distance of not above half a mile from the influence of salt water, and only villages situated within a quarter of a mile were strongly infected. A free aspect, opening upon the sea, seemed to increase this liability.

#### TYPE OF PARASITE ENCOUNTERED.

6. The frequency with which the different types of parasites were met with is shewn in Table VI. It will be seen that at this time of the year the bulk of infections among the native children in the villages were those of Simple Tertian.

### III.—Anopheles of the Andamans.

7. The following species of anopheles were encountered as a result of systematic collection of larvæ and adults:—

*Neostethopheles aitkeni* (James).

*Myzomyia albirostris* (Theobald).

*Nyssomyzomyia rossi* (Giles). (Variety).  
*Nyssomyzomyia ludlowi* (Theobald).  
*Neomyzomyia elegans* (James).  
*Neomyzomyia punctulata* (James and Liston).  
*Nyssorhynchus nivipes* (Theobald). (Variety).  
*Myzorhynchus barbirostris* (Van der Wulp).

Of these species *Nsm. rossi*, *Nsm. ludlowi* and *My. barbirostris* were the commonest. As the total period during which anopheles were collected did not exceed two months it is more than likely that still other species occur. The zoological isolation of the Andamans has not therefore led to a restricted anopheles fauna in the Settlement.

8. *Ns. aitkeni*.—A few specimens of this species were bred out from nymphs taken in a small rocky pool in the bed of a forest stream.

9. *Nm. elegans*.—This species was found breeding in small pools in connection with rocky mountain streams in the forest. It was especially frequent in the streams on Mount Harriet (1,500 ft.). One adult specimen was caught in a bungalow apparently attracted by light.

10. *Nm. punctulata*.—Specimens of this species were caught occasionally in houses and barracks in different parts of the Settlement. It was not found breeding.

11. *N. nivipes*.—About a dozen specimens were bred out from larvæ taken in a ricefield at Jungly Ghat close to a sea embankment. One or two specimens were also taken in a rush swamp near Ogra Baraij. No adults were caught in houses.

Three specimens of *N. nivipes* sent by Major James, I.M.S., from Malay shew nearly a half of the second tarsal segment white. In the specimens collected in the Andamans the amount of white is about the same as in *N. fuliginosus*, i.e., a quarter of the segment or less. The markings on the wings differ only slightly from those in *N. nivipes* from Malay, but the abdominal scales form much more pronounced tufts than do those in the Malay specimens. It is possible that the Andamanese specimens represent a local variety of *N. nivipes*.

12. *M. albirostris*.—This species was occasionally taken in huts, about a dozen specimens altogether having been captured. The characters corresponded with those in a specimen sent to the Bureau from Calcutta of an anopheles recently described by Dr. Brahmachari<sup>(1)</sup> and with those in specimens sent from Burma by Major Lalor, I.M.S., as possibly a new species. As pointed out by Major James all these specimens appeared to be Theobald's *M. listoni* var. *alboapicalis*. But there seemed to be no doubt that they were different from *M. listoni*, and I have previously alluded to this species

as *M. brahmachari*. Since then I have been able to examine specimens of *M. albirostris* from Malay and have satisfied myself that *M. brahmachari* is identical with this species.

At the time of my visit the species was too rare to be an important agent in the transmission of malaria.

13. *My. barbirostris*.—This species was very abundant within the forest where it attacked one freely during the day. Although adults were so common it was very difficult to find larvæ. At several places near the edge of the forest the species was found breeding freely. But within the depths of the forest I only once found any larvæ; this was in a deep hole filled with clear water. There were many pools in connection with small forest streams but no larvæ of this species were ever found in them.

Larvæ of *My. barbirostris* were met with in small numbers in some of the swamps. Some were found in water that was distinctly though very faintly brackish. A large number were at one time taken in a rush swamp where the water though about a foot deep was not visible owing to a dense growth of rushes.

Adults of this species though so numerous in the forest were only very occasionally taken in the huts in the villages and then only as a rule when the hut was close to thick jungle. For this reason I am doubtful whether, even if a good carrier, *My. barbirostris* plays much part in the transmission of malaria in the Settlement. It is possible, however, that it may act as a carrier in the case of forest camps or even in the case of convicts working during the day in the forest. At Dundas Point, a very malarious station, the convicts at the time of my visit were engaged in excavating earth on the borders of the forest. On visiting the spot I readily caught specimen of *My. barbirostris* within the shade of the neighbouring jungle, but none were to be found in a small rest-hut used by the convicts. None of those caught contained any blood or shewed evidence of infection. The forest camps where timber is felled, so far as I could ascertain, are not particularly malarious. That specimens ordinarily encountered in the forest are not infected with malaria is probable and it is noteworthy that though I and my two assistants were constantly being bitten none of us developed malaria.

14. *Nsm. rossi* (variety).—The commonest species in the huts of the Settlement is a variety of *Nsm. rossi* shewing a broader white apical band on the palps than is seen in the ordinary Indian *Nsm. rossi*. From the description given of *Nsm. rossi* (var. *indefinata*) by Ludlow it seems possible that it is this variety. Theobald in 1910 considers it as a distinct species, *Nsm. indefinata*.

Towards the end of September and in October the variety mentioned was found in greater or less numbers in every village examined, including the

healthy villages Tusanabad, Manpur and Wimberleyganj. It was also found at Maymyo, a newly opened and remote inland village where the land was still in process of being cleared.

The species was found breeding as a rule in very small and temporary collections of water in among the houses. A certain number of specimens were also found breeding in small clay puddles on the tops of hills both near and at some distance from villages. As a rule the restriction of breeding places to the village area was very noticeable. Larvæ were never found in ricefields and innumerable pools that in ordinary circumstances one would have expected to find used as breeding places were entirely free from larvæ.

About a hundred specimens caught in huts in Port Mouat were examined for zygotes and sporozoites but with negative result.

15. *Nsm. ludlowi*.—This species was caught in fair numbers at Bamboo Flat, Shore Point, Dundas Point and Phoenix Bay. A few specimens were also caught at Namunagahr and Mitha Khari villages situated on elevated sites but not very far from the sea. None were caught in any of the inland villages.

Very numerous adult specimens were to be obtained from small watchman's huts situated near embankments along the coast. In one tiny hut shown in the photograph accompanying this report nearly a hundred were caught in about half an hour's search. At Haddo, a peninsular surrounded on three sides by the sea, the species was found up to a height of three hundred feet above sea level and half a mile from the shore. As a rule the closest search failed to shew this species more than a quarter of a mile from the influence of salt water.

The larvæ were found in brackish water, notably in pools near the embankments. In one instance the amount of salt was roughly determined as about .4 per cent. Breeding places were, however, not so easily found as might be expected as only a few pools out of many hundreds in the salt swamps contained larvæ. Even when larvæ could not be found it was nevertheless always possible to find adults near these swamps, if there was any suitable collecting place.

In two specimens caught at Port Mouat (out of a total of 53 examined) zygotes of malignant tertian were found.

The relation between the distribution of this species and that of malaria was most exact. The prevalence of *Nsm. ludlowi* explained the unhealthiness of the station at Haddo and of the Female Jail both to all appearance situated on well chosen sites. It was also easy to understand, knowing the habits of the species, why a station known as Perseverance Point should have been found so unhealthy as to necessitate its abandonment. Even if other species transmit

malaria to some extent there can be little doubt that this species is the important carrier in the Settlement.

It is interesting to note that though *Nsm. ludlowi* rather closely resembles *Nsm. rossi* the eggs of the two species are quite distinct; those of *Nsm. rossi* having a very broad frill, whereas those of *Nsm. ludlowi* have a narrow frill and rather resemble in general appearance the eggs of *N. fuliginosus*.

#### CHARACTER OF THE ANOPHELINE FAUNA.

16. In view of the evidence of isolation shown by the mammalian fauna of the Andamans one might have expected that the species of anopheles would be few in number. One would also not be surprised to find a number of local varieties or even distinct species. The question of the recent introduction of species from the mainland is also important.

We have already seen, however, that the number of species represented is quite large and consideration will shew that the anopheline fauna of the Andamans is practically that of the Malay peninsula.

The differences between the anopheline fauna of Port Blair and that of the Indian peninsula is on the other hand very marked. The occurrence of *N. nivipes* in place of *N. fuliginosus*, of *M. albirostris* in place of *M. listoni* and the relative frequency of *Nm. punctulata* are especially noticeable.

The only instance of a local variety is the possible occurrence of a variety of *N. nivipes*.

Had recent introduction of species much influence the fauna one would have expected to find the ordinary Indian *Nsm. rossi* and the very common Indian *N. fuliginosus*. The presence of Malay forms suggests that the anopheline fauna is an indigenous one since the only direct communication with the Andamans is from Calcutta, Madras and Rangoon.

#### NUMERICAL PREVALENCE OF ANOPHELES.

17. In spite of apparently ideal conditions for the breeding of anopheles, they were, with the exception of *My. barbirostris* in the forest, by no means numerous. The huts in the villages, each with an enclosed verandah used as a cow shed, were peculiarly suitable for the detection and capture of adult anopheles. But except at Bamboo Flat and Port Mouat during the first fortnight of my stay the catches made were not at all large. As a rule specimens were to be obtained only as a result of close search.

Within the barracks it was even difficult to find adult anopheles at all. At Dundas Point traps were made by hanging up blankets, etc., in suitable

corners overnight, but even with this assistance the numbers caught were small.

18. Equally striking was the difficulty in finding larvæ. The ordinary pools of the countryside, though apparently most suitable for breeding, practically never contained larvæ. Contrasted with my experience of conditions in the Punjab this was especially remarkable.

19. Whilst one was struck with the paucity of larvæ in situations where these might have been expected to occur, one was impressed with the great prevalence of fish of the genus *Haplochilus*. These were especially abundant in the little pools formed by trickling streams; but they also occurred in almost all water of a permanent character or which was sufficiently permanent to shew any growth of aquatic weeds or algæ. It seems very probable that this prevalence of *Haplochilus* is concerned in preventing many pools, otherwise suitable, from being made use of as breeding places. *Haplochilus* and larvæ of *My. barbirostris* were nevertheless several times found together.

#### IV.--Malaria among the labouring convicts.

20. The most important questions in regard to Malaria in the Andamans relate to the conditions affecting the labouring convicts. It will therefore be necessary to study these in some detail.

##### NATURE OF ADMISSIONS FOR MALARIA.

21. In order to see to what extent admissions to the hospitals for malaria are actually due to this disease, the blood of 104 consecutively admitted cases was examined on arrival at hospital. The results of this examination are shewn in Tables II and IV.

TABLE II.

Serial number.	Work.	Condition of spleen.	Anamia.	Temperature.	Species of parasite.	Number of parasites per 100 microscopic fields.	Percentage of large mono-nuclears. Pigment.	Number of fields examined.	Probable disease.	REMARKS.
1	Grass cutting	Nil	Yes	101	Nil	—	3	800	?	Leucocytosis (Later diagnosed as pleurisy).
2	Road work	To umbilicus	Yes	—	Nil	—	7	300	?	
3	...	Nil	No	—	Quartan	3	...	200	Malaria.	
4	...	Nil	No	101.4	Tertian	2	...	200	Malaria.	
5	...	Nil	No	—	Nil	—	7	400	?	
6	...	Nil	No	—	Nil	—	7	300	?	
7	...	Palpable	Yes	—	Quartan	2	...	...	Malaria.	
8	Boatman	* Nil	No	99	Nil	—	11.5	500	Malaria.	
9	...	Handsbreadth	Yes	100.2	Nil	—	...	500	?	
10	Boatman	3 fingers	Yes	99.2	Nil	—	6	300	?	
11	Grass cutting	Nil	No	99.2	Quartan	2	17	400	Malaria.	
12	Quarries	4 fingers	Yes	98.8	Nil	—	10	500	Malaria.	
13	Grass cutting	Palpable	Yes	99.8	Nil	—	2	500	?	
14	...	4 fingers	Yes	98.8	Nil	—	9	400	?	Possibly malaria.
15	Excavation	2 fingers	Yes	99.4	Tertian	9	...	100	Malaria.	
16	Wood cutting	Nil	Yes	103	Nil	—	Pigment	300	Malaria.	
17	Coolie	Palpable	?	98.6	Nil	—	6	600	?	
18	Excavation	Nil	?	100.2	Tertian	3	...	200	Malaria.	
19	Bund repairs	Nil	No	98.6	Nil	—	7	500	?	

TABLE II—continued.

Serial number.	Work.	Condition of spleen.	Anemia.	Temperature.	Species of parasite.	Number of parasites per 100 microscopic fields.	Percentage of large mono-nuclears. Pigment.	Number of fields examined.	Probable disease.	REMARKS.
20	Cane cutting	Palpable	Yes	99.4	Quartan	80	...	50	Malaria.	
21	Coolie	Nil	No	99.8	Tertian	3	...	200	Malaria.	
22	Excavation	Handsbreadth	Yes	99.6	Quartan	2	—	200	Malaria.	
23	...	Handsbreadth	Yes	99.2	Nil	—	8.5	600	P	Marked polychromasia. Possibly malaria.
24	...	Nil	No	98.6	Nil	—	.5	600	P	Ditto
25	..	Nil	Yes	99	Quartan	.5	...	200	Malaria.	
26	...	Handsbreadth	Yes	99.6	Nil	—	12	600	Malaria.	
27	Peon	To umbilicus	Yes	100	Nil	—	9	1,000	P	Possibly malaria.
28	...	...	...	98.8	Nil	...	...	...	...	
29	Excavation	...	...	100.4	Quartan	35	...	50	Malaria.	
30	...	...	...	98.6	Nil	—	2.5	600	P	
31	Coolie	Nil	P	100.2	Nil	...	...	400	P	
32	Road work	Nil	No	99	Nil	—	5.5	400	P	
33	Waterman	4 fingers	Yes	104.2	Nil	—	3	400	P	Leucocytosis (Pneumonia).
34	Waterman	3 fingers	Yes	99	Quartan and tertian.	5	...	100	Malaria.	
35	Peon	Nil	Marked	...	Nil	—	...	...	P	
36	Excavation	Handsbreadth	Yes	104	Nil	—	4	600	P	

TABLE II—continued.

Serial number.	Work.	Condition of spleen.	Anemia.	Temperature.	Species of parasite.	Number of parasites per 100 microscopic fields.	Percentage of large mono-nuclears. Pigment.	Number of fields examined.	Probable disease.	REMARKS.
37	Gardener .	Nil	No	98	Nil	—	7	400	P	
38	Excavation .	Nil	Yes	99.4	Quartan .	10	...	100	Malaria.	
39	Quarry .	Nil	Yes	98	Tertian .	5	...	100	Malaria.	
40	Quarry .	Nil	Slight	97.8	Nil	—	5	400	P	
41	Excavation .	3 fingers .	No	98.2	Nil	...	24	400	Malaria.	
42	Excavation .	3 fingers .	Marked	98.8	Quartan .	10	...	100	Malaria.	
43	Coolie .	Nil	No	100.8	Malignant tertian.	2	...	200	Malaria.	
44	Watchman .	Nil	Yes	97.8	Nil	—	13	400	Malaria.	
45	Road ramming .	Nil	No	103.8	Tertian .	3	5.5	400	Malaria.	Developed pneumonia.
46	Brickmaking .	Palpable .	Slight	99.2	Tertian .	2	...	100	Malaria.	
47	Boatman .	3 fingers .	Intense	99	Nil	—	14	600	Malaria.	
48	Cane cutting .	Nil	No	101	Nil	—	20	400	Malaria.	
49	Excavation .	Palpable .	No	99	Nil	—	9.5	400	P	
50	Cane cutting .	Nil	No	99	Tertian .	9	...	100	Malaria.	
51	Cocoanut file .	Palpable .	No	102	Quartan and tertian.	545	...	20	Malaria.	
52	Watchman .	Handsbreadth .	Yes	98	Quartan .	3	...	100	Malaria.	
53	Road ramming .	Nil	No	102.4	Nil	—	5	400	P	

TABLE II—continued.

Serial number.	Work.	Condition of spleen.	Anæmia.	Temperature.	Species of parasite.	Number of parasites per 100 microscopic fields.	Percentage of large mono-nuclears. Pigment.	Number of fields examined.	Probable disease.	REMARKS.
54	Road ramming	Nil	Slight	102.6	Tertian	3	...	300	Malaria.	Developed pneumonia.
55	Excavation	Palpable	No	102.2	Nil	—	7	400	P	
56	Firewood	Nil	Slight	...	Tertian	2	...	100	Malaria.	
57	Cocconut file.	Nil	No	101	Nil	—	5	400	P	
58	...	Palpable	Slight	...	Quartan and tertian.	2	...	200	Malaria.	
59	...	...	...	...	Nil	—	3	400	Pneumonia	
60	Road work	Nil	No	99.2	Nil	—	6	400	P	
61	Cocconut file.	Nil	No	103.8	Nil	—	2	400	P	
62	Brickwork	Nil	No	99.2	Nil	—	4	400	P	
63	Road work	Palpable	No	101.6	Nil	—	6	400	P	
64	Thatching	Nil	Slight	103.8	Nil	—	5	400	P	
65	Coolie	Palpable	Slight	99.4	Quartan and tertian.	35	...	50	Malaria.	
66	Road work	Nil	No	100.6	Nil	—	15	400	Malaria.	
67	Excavation	Nil	Yes	99	Quartan and tertian.	4	...	100	Malaria.	
68	Boatman	3 fingers	No	98.2	Nil	—	3	400	P	

TABLE II—continued.

Serial number.	Work.	Condition of spleen.	Anemia.	Temperature.	Species of parasite.	Number of parasites per 100 microscopic fields.	Percentage of large mono-nucleated forms. Pigment.	Number of fields examined.	Probable disease.	REMARKS.
69	Cane cutting	Palpable	No	98	Quartan	5	5.5	400	Malaria.	
70	Carpenter	Nil	No	...	Nil	—	—	400	?	
71	Thatching	Nil	Yes	...	Tertian	22	—	100	Malaria.	
72	Coolie	3 fingers	Slight	99	Nil	—	2	400	?	
73	Bricklayer	Nil	Yes	97.4	Nil	—	7	400	?	
74	Sweeper	4 fingers	Yes	99.4	Nil	—	3	400	?	
75	Road work	Nil	No	97.2	Quartan	—	—	400	Malaria.	
76	Cane cutting	Handsbreadth	Yes	100.2	Quartan	8	—	200	Malaria.	
77	Brickmaking	Nil	No	99	Quartan	2	—	200	Malaria.	
78	Road work	Handsbreadth	Yes	99.4	Nil	—	7	400	?	
79	Grass cutting	Nil	Yes	100.8	Tertian	5	—	200	Malaria.	
80	Watchman	Handsbreadth	Marked	100.2	Tertian	1	—	200	Malaria.	
81	Watchman	Nil	Slight	99	Nil	—	—	400	?	
82	Road work	Palpable	Yes	100.6	Tertian	16	—	100	Malaria.	
83	Coolie	4 fingers	Yes	99.4	Nil	—	4	400	?	
84	Sweeper	Nil	Yes	100.4	Quartan	4	—	100	Malaria.	
85	Road work	3 fingers	Yes	103.6	?	—	—	400	?	
86	Engine driver	Nil	No	98.4	Nil	—	3	400	?	

TABLE II—concluded.

Serial number.	Work.	Condition of spleen.	Anemia.	Temperature.	Species of parasite.	Number of parasites per 100 microscopic fields.	Percentage of large mono-nucleate forms. *Pigment.	Number of fields examined.	Probable disease.	REMARKS.
87	Fisherman . . .	Nil	No	101.2	Nil	—	7	400	?	
88	Cane cutting . . .	Nil	No	101.0	Nil	—	4	400	?	
89	Blacksmith . . .	Nil	No	99.4	Nil	—	18	300	Malaria.	
90	Saw Mills . . .	Nil	No	98	Nil	—	—	400	?	
91	Coolie . . .	Nil	Slight	98.2	Tertian .	1	—	200	Malaria.	
92	Carpenter . . .	Nil	Slight	96	Nil	—	—	400	?	
93	Boatman . . .	Handsbreadth	Slight	98.6	Tertian .	5	—	200	Malaria.	
94	Coolie . . .	Nil	No	98.6	Nil	—	6	400	?	
95	Light labour . . .	Nil	No	98.4	Nil	—	12	400	Malaria.	
96	Jungle work . . .	Nil	No	99	Nil	—	—	400	?	
97	Carpenter . . .	Nil	No	96	Tertian .	8	—	100	Malaria.	
98	Coolie . . .	Nil	No	99.2	Quartan .	40	—	50	Malaria.	
99	Stonework . . .	To umbilicus	Marked	96.4	Nil	—	—	400	?	
100	Stonework . . .	Nil	No	97	Nil	—	9	400	?	
101	Saw Mills . . .	Nil	Yes	97	Nil	—	10	400	Malaria.	
102	Coolie . . .	Nil	Yes	97.4	Quartan .	1	—	200	Malaria.	
103	Coolie . . .	Nil	No	96.2	Quartan .	6	—	200	Malaria.	
104	Coolie . . .	Nil	No	98.2	Quartan .	6	—	100	Malaria.	

TABLE III.

Serial No.	Spleen.	Anæmia.	Parasite.	Number of parasites per 100 fields.	Percentage of large mononuclears.	Number of fields examined.	Probable disease.
1	To umbilicus .	Marked .	<i>Nil</i> .	...	...	...	?
2	To umbilicus .	Intense .	<i>Nil</i> .	...	6	1,200	?
3	Handsbreadth .	Yes .	<i>Nil</i> .	...	...	200	?
4	<i>Nil</i> .	No .	<i>Nil</i> .	...	...	200	?
5	<i>Nil</i> .	Slight .	<i>Nil</i> .	...	...	200	?
6	Palpable .	Yes .	<i>Nil</i> .	...	...	200	?
7	Handsbreadth .	No .	<i>Nil</i> .	...	...	200	?
8	Palpable .	Slight .	Quartan .	110	...	50	Malaria.
9	<i>Nil</i> .	Yes .	<i>Nil</i> .	...	...	...	?
10	4 fingers .	Slight .	Tertian .	2	...	200	Malaria.
11	Handsbreadth .	Marked .	Quartan .	1	...	200	Malaria.
12	<i>Nil</i> .	?	Tertian .	8	...	200	Malaria.
13	Palpable .	Yes .	<i>Nil</i> .	...	...	200	?
14	To umbilicus .	Yes .	<i>Nil</i> .	...	...	200	?
15	<i>Nil</i> .	?	<i>Nil</i> .	...	...	200	?
16	Handsbreadth .	Slight .	Tertian .	1	...	200	Malaria.
17	<i>Nil</i> .	Yes .	<i>Nil</i> .	...	...	400	?
18	Handsbreadth .	Slight .	<i>Nil</i> .	...	...	200	?
19	Handsbreadth .	No .	<i>Nil</i> .	...	...	200	?
20	<i>Nil</i> .	No .	<i>Nil</i> .	...	17	600	Malaria.
21	...	...	<i>Nil</i> .	...	...	200	?
22	2 fingers .	Marked .	Quartan .	6	...	100	Malaria.
23	<i>Nil</i> .	No .	<i>Nil</i> .	...	...	200	?
24	Palpable .	No .	<i>Nil</i> .	...	...	200	?
25	<i>Nil</i> .	Slight .	<i>Nil</i> .	...	...	400	?
26	<i>Nil</i> .	?	<i>Nil</i> .	...	...	200	?
27	Handsbreadth .	Slight .	<i>Nil</i> .	...	...	200	?
28	<i>Nil</i> .	No .	<i>Nil</i> .	...	...	200	?
29	Palpable .	No .	<i>Nil</i> .	...	...	200	?
30	Palpable .	Yes .	<i>Nil</i> .	...	...	200	?
31	<i>Nil</i> .	Yes .	<i>Nil</i> .	...	2.5	600	?
32	<i>Nil</i> .	No .	<i>Nil</i> .	...	5	400	?

TABLE IV.

	Total number examined.	Number shewing parasites.	Not shewing parasites but with pigment or mononuclear increase.	Not shewn in other headings but with marked enlargement of spleen, and anæmia.	Percentage of certain malaria.	Percentage of probable malaria.
Consecutive admissions to hospital.	101	42	12	11	43	61
Convalescent gang .	32	6	1	8	19	47

It will be seen that parasites were detected in 43 per cent. of the admissions. Taking into consideration the presence of pigmented cells and a markedly raised percentage of large mononuclears an additional 11 per cent. shewed evidence of malaria. Considering also marked enlargement of the spleen associated with anæmia and fever a total of 61 per cent. of the admissions must be considered as certain or probable cases of malaria.

22. In addition to cases examined on admission to hospital 32 men taken at random from among the convalescents (Convalescent gang) also shewed a considerable degree of infection. *Vide* Tables III and IV.

23. In spite of the high percentage of positive malaria cases the numerical value of the infections was on the whole very low. Table V.

#### TYPE OF PARASITE ENCOUNTERED.

24. The relative proportion of the different species of parasite met with in the case of admissions at Viper Island and at Haddo and among the convalescent gang at Viper Island is shewn in Tables V and VI.

If we consider the proportion of quartan usually found in an infected community it is evident that among the labouring convicts there is a remarkable relative preponderance of this form of parasite. This relative prepon-

derance is not shewn by the children in the villages. The significance of these facts will be dealt with in a later section.

TABLE V.\*

	Under 10 parasites per 100 fields.	Ten and under 20 parasites per 100 fields.	Twenty and under 50 parasites per 100 fields.	Fifty parasites and over per 100 fields.	Under 10 parasites per 100 fields.	Ten and under 20 parasites per 100 fields.	Twenty and under 50 parasites per 100 fields.	Fifty parasites and over per 100 fields.	Under 10 parasites per 100 fields.	Ten and under 20 parasites per 100 fields.	Twenty and under 50 parasites for 100 fields.	Fifty parasites and over per 100 fields.
Children . . . . .	8	1	3	0	4	...	...	...	...	...	1	...
Admissions to hospital . . . . .	20	1	1	0	17	2	3	2	1	...	...	...
Convalescent gang . . . . .	3	...	...	...	2	...	...	1	...	...	...	...
Labouring convicts . . . . .	2	...	...	...	3	...	...	...	2	...	...	...
Total adults . . . . .	25	1	1	0	22	2	3	3	3	...	1	...

TABLE VI.\*

		Number of infections.
Children . . . . .	Simple tertian . . . . .	12
	Quartan . . . . .	4
	Malignant tertian . . . . .	1
Adults . . . . .	Simple tertian . . . . .	27
	Quartan . . . . .	30
	Malignant tertian . . . . .	3

\* NOTE.—Double infections are entered as separate infections according to the number of each type of parasite found.

#### ANNUAL AND SEASONAL VARIATIONS IN MALARIA.

25. The monthly admissions for malaria at the three large hospitals in the Settlement for the years 1907 to 1911 are given in Table VII.

TABLE VII—SHOWING MONTHLY ADMISSIONS FOR  
MALARIA, 1907-1911.

	VIPER.			HAEDO.		BAMBOO FLAT.	
	Admissions, total.	Admissions, Fever.	Rainfall.	Admissions, total.	Admissions, Fever.	Admissions, total.	Admissions Fever.
1907.							
June . . . . .	1,210	992	9.42	...	...	...	...
July . . . . .	1,164	908	24.35	645	414	...	...
August . . . . .	797	647	12.34	563	354	...	...
September . . . . .	582	486	10.72	512	314	669	455
October . . . . .	599	462	15.37	573	390	644	436
November . . . . .	488	349	28.18	457	263	658	457
December . . . . .	567	392	10.65	451	260	577	352
Total . . . . .	5,407	4,236	...	3,201	1,995	2,548	1,700
Percentage of malaria to total.	78%			62%		66%	
1908.							
January . . . . .	478	332	0.42	330	63	570	323
February . . . . .	490	331	4.65	276	80	469	228
March . . . . .	486	369	0.01	383	209	519	275
April . . . . .	393	238	1.36	419	238	538	327
May . . . . .	532	343	31.59	496	269	589	340
June . . . . .	645	493	21.81	583	346	708	471
July . . . . .	958	720	21.55	455	276	753	472
August . . . . .	644	449	26.57	351	165	654	407
September . . . . .	478	294	18.68	413	244	561	309
October . . . . .	343	206	7.78	339	196	462	251
November . . . . .	321	208	8.66	437	211	409	252
December . . . . .	265	162	7.31	338	169	531	266
Total . . . . .	6,033	4,115	...	4,820	2,466	6,793	3,921
Percentage of malaria to total.	68%			51%		57%	



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TABLE VII—SHOWING MONTHLY ADMISSIONS FOR  
MALARIA, 1907-1911—*contd.*

	VIPER.			HADDO.		BAMBOO FLAT.	
	Admissions, total.	Admissions, Fever.	Rainfall.	Admissions, total.	Admissions, Fever.	Admissions, total.	Admissions, Fever.
1909.							
January . . . . .	377	251	0.05	344	183	459	219
February . . . . .	223	119	3.12	230	281	503	262
March . . . . .	350	222	3.18	630	482	604	370
April . . . . .	403	281	6.88	697	518	595	369
May . . . . .	583	477	18.60	717	454	...	...
June . . . . .	797	657	25.03	839	579	862	439
July . . . . .	713	583	21.96	832	558	797	475
August . . . . .	649	384	20.79	535	323	720	413
September . . . . .	432	281	23.35	481	284	584	314
October . . . . .	348	175	21.30	398	242	641	339
November . . . . .	396	219	26.51	344	173	704	385
December . . . . .	381	223	3.88	295	125	374	304
Total . . . . .	5,652	3,872	...	6,542	4,202	7,043	3,889
Percentage of malaria to total.	68%			64%		55%	
1910.							
January . . . . .	323	200	2.05	256	102	...	...
February . . . . .	325	167	1.03	210	92	...	...
March . . . . .	268	167	8.32	284	179	...	...
April . . . . .	296	147	4.04	364	266	...	...
May . . . . .	543	413	7.11	605	429	...	...
June . . . . .	562	449	20.51	787	588	...	...
July . . . . .	665	530	10.34	757	598	...	...
August . . . . .	387	294	12.61	568	398	...	...
September . . . . .	321	192	27.94	375	241	...	...
October . . . . .	270	175	10.02	312	165	...	...
November . . . . .	318	188	16.41	318	146	...	...
December . . . . .	341	185	3.15	416	148	...	...
Total . . . . .	4,559	3,107	...	5,252	3,352	...	...
Percentage of malaria to total.	68%			63%		...	

TABLE VII—SHOWING MONTHLY ADMISSIONS FOR  
MALARIA, 1907-1911—*concl'd.*

	VIPER.			HADDU.		BAMBOO FLAT.	
	Admissions, total.	Admissions, Fever.	Rainfall.	Admissions, total.	Admissions, Fever.	Admissions, total.	Admissions, Fever.
1911.							
January . . . . .	352	189	...	344	142	...	...
February . . . . .	354	190	0.54	347	147	...	...
March . . . . .	326	155	...	286	133	...	...
April . . . . .	316	161	4.84	288	117	...	...
May . . . . .	480	278	11.96	334	147	...	...
June . . . . .	483	373	34.15	550	368	...	...
July . . . . .	410	292	12.64	570	348	...	...
August . . . . .	283	210	7.70	...	...	...	...
September . . . . .	254	185	...	...	...	...	...
Total . . . . .	3,298	2,033		2,659	1,402	...	...
Perc. of malaria to total	61%			53%		...	

In each of these years the number of admissions is smallest during the period October to March. There then occurs a sharp rise in the number of admissions usually first evidenced in the numbers for May and reaching a maximum in June or July. At this time the number of admissions is from two to four times that of the non-malaria season. During the months of August and September the number of admissions gradually diminishes till the low level of the succeeding non-malaria season is reached.

26. Considerable variations in the intensity and continuance of the fever rise occur in different years. Some years, *e.g.*, 1907, are especially malarious, others, as was the case in 1911, are especially healthy.

#### RELATION OF THE MALARIA SICK RATE TO RAINFALL.

27. In Table VII opposite the number of admissions in the month at Viper are given the number of inches of rainfall. It will be seen that the period of least malaria prevalence is characterised by a low rainfall and that the onset of the rains and the rise in fever admissions are almost synchronous. It will also be noticed that the much prolonged fever season of 1907 was

associated with an unusual continuance of the rains. On the other hand, in most years the fever rate decreases before there is a cessation of the rains.

The reason for the latter relation is not clear but the simultaneous onset of the rains and fever season supports the view discussed later that relapses play a large part in the fever season of the Andamans as has been noted by Deeks and James<sup>(2)</sup> in the case of Panama.

#### RELATION OF MALARIA SICK RATE TO OCCUPATION.

28. It is the common experience in the Andamans that certain kinds of convict labour are more associated with malaria than others. The type of labour most associated with a high prevalence of fever is excavation work, repairing of embankments, road making and certain kinds of jungle work. At the time of my stay quite a number of cases were admitted from among those employed in cutting canes in the jungle. All the types of work mentioned are especially associated with exposure to sun and rain and with severe bodily exertion. The relation of arduous physical exertion to the malaria of excavation has not been previously noted. It is possible, however, that this factor by favouring the occurrence of relapses plays some part. In regard to the cane cutters, whose work would not seem to be so arduous, I afterwards discovered that, as canes were becoming increasingly scarce in the neighbourhood of the barracks, the men cutting them had to walk long distances in order to find them. I believe at that time cane cutting was in fact an unusually arduous occupation.

The following table taken from the 1901 census shews the relation of labour to malaria admissions in actual figures:—

Nature of work.	Strength.	Number sick (malaria).	Convalescent (malaria).	Readmissions (malaria).	Percentage ineffective.
Indoor work—					
Ordinary . . . . .	2,681	40	18	2	2.23
Hard . . . . .	1,217	40	31	4	6.16
Outdoor work—					
Ordinary . . . . .	5,597	128	96	21	4.37
Hard . . . . .	3,228	153	168	15	10.4

The same relation to occupation is shewn in the following figures also taken from the census :—

Locality.	Nature of work.	Average of 3 days percentage sick (malaria) to strength.
Bajajag . . . . .	Firewood and forestry . . . . .	15.15
Dundas Point . . . . .	Brickfields . . . . .	10.54
Namunagahr . . . . .	Quarries and firewood . . . . .	9.33
Goplakabang . . . . .	Tea garden and forestry . . . . .	8.90
Navy Bay . . . . .	Tea gardens . . . . .	8.18

The data given in this table may be influenced by the fact that localities where certain kinds of work are carried out are especially malarious. On the other hand, stations like Dundas Point where the barracks shew but few anopheles, but where nevertheless the convicts suffer much from malaria, may be unhealthy largely because of the nature of the work carried out there (excavation).

Many of the cases whose blood was examined came from Dundas Point; the fact that they suffered mainly from quartan infection is a very important one. As will be shewn later such a predominance of quartan does not favour the view that infection was especially active but rather indicates that at Dundas Point the raised fever incidence owes its origin very largely to the prevalence of relapses.

#### V.—Considerations upon the nature of malarial infection in different communities in the Andamans.

29. Many observations have been made upon the proportionate prevalence of the different species of parasites in different countries and localities; but no explanation to account for the variations has ever been given. It seems possible that such a prevalence depends upon conditions the nature of which will be discussed in this section.

##### RELATION TO THE NUMERICAL PREVALENCE OF ANOPHELES.

30. In the Punjab the prevalence of malignant tertian among the native community is greatest during the fever season, *i.e.*, the period of greatest anopheles prevalence (August to October). As anopheles disappear and infec-

tion becomes reduced crescents are still numerous but infections with malignant tertian ring forms are scanty. Still later in December and January in certain places which had been very intense foci of malaria (parts of Amritsar and Delhi) a high relative prevalence of quartan was encountered, apparently due to the greater relative reduction of other forms of parasite. In such cases though, at the time, the parasite rate was not very high there was a very high spleen rate (approaching 100 per cent).

31. A relative preponderance of quartan is also seen over quite large areas in certain parts of India. A high quartan rate prevails throughout the Duars, an area in which, as shewn by Christophers and Bentley,<sup>3</sup> factors favouring residual infection prevail and in which the number of anopheles was often disproportionately small as compared with the amount of fever present.

In the highly endemic Jeypore Agency Tract in the dry season, associated with scanty anopheles and a high spleen rate, Major Perry informs me that quartan is the predominant type of parasite. It seems possible that a high relative quartan prevalence in these large areas may be due to conditions somewhat similar to those clearly seen at work in the small Punjab foci described above.

32. A relative increase in the proportion of malignant tertian associated with the period of greatest infection is also shewn by Mathis and Leger<sup>4</sup> for the parasite rate in different seasons and for different localities in Tonkin (Tables VIII and IX).

TABLE VIII.

		MAY TO SEPTEMBER.			OCTOBER TO APRIL.		
		Number infected.	Percentage proportion.	Parasite rate (Haut-Tonkin.)	Number infected.	Percentage proportion.	Parasite rate (Haut-Tonkin.)
Children	Malignant tertian .	48	27.9	8.1	53	41.4	17.5
	Simple tertian .	95	55.23		55	42.96	
	Quartan .	29	16.86		20	15.62	
Adults	Malignant tertian .	71	54.6	...	212	71.6	...
	Simple tertian .	53	40.7		69	23	
	Quartan .	6	4.6		15	5	

TABLE IX.

	Delta.	Hoabinh.	Tuyen- Quang.	Hagiang.	Sonla.	Laokay.
Number of infected children . . . . .	66	29	30	25	60	51
Endemic index . . . . .	3%	19%	16%	33%	37%	14%
Percentage proportion of Simple tertian.	80	90	60	40	22	16
Percentage proportion of Malignant tertian.	20	7	17	26	72	41
Percentage proportion of Quartan . . . . .	...	3	23	24	7	43

The very high quartan rate at Laokay it may be noticed is associated with a low parasite rate though the other hilly parts of Tonkin shew a high rate. It is possible that this is an example similar to those already mentioned in India of a temporary reduction of the total index and a relative preponderance of quartan.

#### INFLUENCE OF THE HUMAN HOST.

33. In the Duars and other malarious areas one often finds that though the native children shew a considerable proportion of each of the three types of parasite, Europeans living in the neighbourhood when they suffer from fever generally shew malignant tertian infection. Dr. Bentley has informed me that he has had a similar experience. Such a relation is shewn on a large scale in the Punjab where among British troops infections with malignant tertian are much more frequently seen in the cases admitted to military hospitals than in infected native children.

The excellent figures of Mathis and Leger for Tonkin also shew this relation very clearly. It will be seen from the following abstract of their results that whilst in adults (both native and European) the malignant tertian incidence is very high it is much less so in the case of native children. (Table X).

TABLE X.

	Malignant tertian.	Simple tertian.	Quartan.
Children 0 to 5 . . . . .	28.57	55.84	15.58
.. 5 to 15 . . . . .	50.72	30.43	18.84
Indigenous adults . . . . .	70.04	11.52	18.43
European adults . . . . .	66.42	28.63	4.92

PECULIARITIES IN THE BEHAVIOUR OF THE DIFFERENT  
SPECIES OF PARASITE.

34. The number of crescents produced and the length of time crescent output continues is a very marked feature of malignant tertian infection. In the case of quartan on the contrary several observers, *e.g.*, Marchiafava and Bignami,<sup>5</sup> have noted the rarity with which flagellating forms are seen. Stephens and Christophers<sup>6</sup> when working at transmission through different species of anopheles found it very difficult to get cases shewing quartan flagellate forms. More recently James<sup>7</sup> studying the quartan parasite at Panama notes that he very rarely saw flagellation in this type of parasite.

Simple tertian produces gametes readily but my experience would suggest that these are neither so numerous nor so continuously produced as in malignant tertian.

35. If such a relation regarding gamete output does hold good then a greater proportion of anopheles will be infected, other things being equal, with malignant tertian than with either of the other forms of parasite. Also new infections will be in a greater proportion those of malignant tertian. And the larger the number of anopheles carrying, *i.e.*, the greater the predominance of new infections, the more the malignant tertian parasite will be represented in the blood of a community.

36. Again the fact that malignant tertian disappears more rapidly than the other forms of parasite from the blood of communities when these are no longer exposed to reinfection suggests that the relapsing power of malignant tertian over long periods is less than that of the other two types of parasite.

In quartan the power of the parasite to maintain itself in the human host in the absence of treatment has often been commented upon. Marchiafava and Bignami<sup>8</sup> say "while in quartan fever the groups of attacks follow each other with the greatest obstinacy separated by longer or shorter intervals of apyrexia—a fact well known to physicians from the most remote period, and the infection in some cases dies out only after many years of existence, even when the patient is living under the most favourable conditions."

When therefore fresh infection is at a minimum and the infection in a community is maintained by relapses it is reasonable to suppose, if a quartan has a greater power of retaining its hold than other parasites, that the proportionate prevalence of this parasite will be raised. When anopheles are very scanty and the factors favouring prolonged infection are very pronounced we should expect to get quartan in its greatest relative predominance. This as we have seen appears to be what actually occurs.

37. It is on considerations of this kind that I explain the conditions at the Andamans. The native children in the villages shew very much the conditions seen elsewhere in India. The labouring convicts being less exposed to anopheles but subject to factors greatly favouring relapses shew the remarkable incidence of quartan noted. In this case we can exclude the possibility of species of anopheles determining the type of infection because the same species acts as the carrier in both cases.

It is possible that the year of my visit being an unusually healthy one the relative preponderance of quartan was greater than usual and that in severely malarious years malignant tertian may be relatively more in evidence. If, on the other hand, cases occurring in the fever season are largely due to increase in the number of relapses the relative prevalence of quartan seen in 1911 may be a permanent and characteristic feature of infection in this community. Only further observations can determine this point.

38. In Panama, Deeks and James<sup>2</sup> refer to malignant tertian as pre-eminently the relapsing type. This would seem to be adverse to the view taken above. But it is necessary to take into account the relative frequency of relapses at longer or shorter period after primary infection. If relapses in malignant tertian were especially frequent for a comparatively short period after the initial infection, this parasite might be responsible for the majority of relapses at Panama where anopheles are fairly numerous. And if a characteristic of quartan is the power of producing more relapses after long periods than is the case with other parasites, quartan might be the most important in the Andamans where anopheles are less numerous.

The fact that treatment is more readily effective in some forms than others of parasite has also to be taken into account when comparing treated with untreated communities.

In a private communication recently received Dr. James informs me that experience at Panama does not in his opinion in any way contradict my conclusions, as owing to the climatic conditions at Panama there are no long periods during which infection is in abeyance.

## VI.—Sickness.

39. A report upon the conditions relating to malaria in the Andamans would be incomplete without some detailed reference to features connected with sickness and mortality. As will be seen in the succeeding sections the exact part played by malaria in this respect is by no means so simple a matter as might be thought. It is not often that the exact fashion in which malaria affects a native tropical community has been described. We do not know for

example exactly how malaria kills in the case of those terrible epidemics which from time to time visit the Punjab and certain other parts of India, or the exact natural history of its action upon the death rate in highly endemic areas. The conditions in the convict settlement are from this point of view unique since not only is every member of the community under close observation, but in the case of death an autopsy is performed as a routine practice. I have therefore taken some pains to make what use I could of these unique conditions.

#### RELATIVE EFFECT OF MALARIA AND OTHER DISEASES ON THE SICK RATE.

40. From Table VII it will be seen that at Viper hospital malaria admissions account for from 60 per cent. to 80 per cent. of the total admissions in the different years given. At Haddo hospital which draws its inmates largely from Aberdeen and stations to the south of the harbour (relatively healthy area) the proportion of admissions for malaria is from 51 per cent. to 64 per cent. of the whole. At Bamboo Flat the proportion is from 55 per cent. to 66 per cent.

From the results of blood examinations given in Tables II and III it may be assumed that at least 40 per cent. of the admissions are cases shewing parasites (positive malaria of Deeks and James) whilst another 20 per cent. are probable cases of this disease (clinical malaria of Deeks and James).

Again from Table VII it will be seen that the total number of admissions for diseases other than malaria does not show as a rule any great variation. Whenever any large increase in admissions takes place it is due to an increase in the number of fever cases.

By far the most important cause influencing the admission rate is therefore malaria and we may for all practical purposes when considering variations in the sick rate take these as being due to malaria.

41. In addition to the direct effect of malaria which these figures indicate it is also possible that malaria is responsible for an increased rate among certain other diseases, *e.g.*, pneumonia. This effect of malaria will be discussed more fully under the section dealing with the death rate.

42. It is also necessary to note the effect of malaria in bringing about a condition of more or less permanent invalidism. At each of the large hospitals there are what are known as "Convalescent" and "Light Labour" gangs. The former is made up of patients who have been discharged from hospital but are not yet fit to return to labour, the latter are convicts not considered fit for ordinary labour but able to do light tasks. Both groups must be considered as a permanent addition to the sick list; not only are convicts in these gangs

“ineffectives” but they are a source of increase to the admission list since they are liable to frequent readmission to hospital.

In Table III it will be seen that out of 32 men taken at random from the convalescent gang 6 or 19 per cent. shewed parasites. In Table XI are given the spleen rates for men in these gangs, for the non-sick labouring convicts and for the self-supporters. It will be seen that a greatly enlarged spleen is present in a very high proportion of the men in the convalescent and light labour gangs and there is little doubt but that these gangs are largely swelled through the effect of malaria.

TABLE XI.

	Number examined.	Very large spleen.		Moderately enlarged spleen.		Total spleen.	
		No.	Per cent.	No.	Per cent.	No.	Per cent.
Cases admitted for fever	101	18	18	22	22	40	40
Convalescent gang	32	11	34	6	19	17	53
Light labour gang	32	8	25	6	19	14	44
Convicts at labour at Dundas Point and Port Mouat.	146	18	12	24	16	43	29
Adults (self-supporters) in unhealthy villages.	124	10	8	16	13	26	21

43. Even the numbers of sick shown by adding together those in hospital and in the convalescent and light labour gangs does not fully exhibit the true prevalence of malaria among the labouring convicts. At Dundas Point among a batch of men at work on excavation in addition to two out of a total of 35 who showed parasites five were obviously more or less sick (anæmia, spleen to umbilicus, etc.). Similarly at Port Mouat and to a less extent at other unhealthy stations examined there was a considerable amount of this kind of unfitness.

44. The aggregate effect of malaria in producing sickness among the labouring convicts in the Andamans is therefore very considerable. The degree to which this community suffers is also greater than that to which the self-supporters in the villages are subject though as regards number of anopheles and conditions apparently suitable for malaria the villages should be more unhealthy than the barracks.

## LENGTH OF STAY IN HOSPITAL.

45. An analysis of the lengths of detention in the Viper Hospital during the period 1st January to 19th February (healthy period) and during the period 1st to 19th July (severe malaria prevalence) gave results as follows :—

Length of period of detention.	HEALTHY PERIOD (50 DAYS).		UNHEALTHY PERIOD (19 DAYS).	
	Number.	Rate per day.	Number.	Rate per day.
1 day . . . . .	7	·54	4	·21
2 days . . . . .	13	·26	61	3·21
3 „ . . . . .	21	·42	75	3·95
4 „ . . . . .	38	·76	72	3·79
5 „ . . . . .	33	·66	77	4·05
6 „ . . . . .	33	·66	44	2·32
7 „ . . . . .	26	·52	22	1·15
8 „ . . . . .	17	·34	11	·57
Total 1 to 8 days . . . . .	188	3·42	366	18·68
Total over 8 days . . . . .	355	7·10	112	5·89

There is therefore no increase but even a reduction in the number of cases lasting over 8 days during the fever season. The greatest increase during severe malaria prevalence is in the number of cases lasting two to five days. This is important as showing that the increase in the number of admissions during the fever season is not accompanied by a corresponding increase in the intensity of the cases. It would seem from these figures that most of the cases admitted even in the height of the fever season in a bad year were mild attacks of malaria. Otherwise the patients could scarcely have been discharged even into the convalescent gang in such a short space of time. Such a state of affairs is more what one would expect with an increase in the number of relapses than with any great increase in the intensity of fresh infections. With any great increase in the amount of transmission of malaria one would expect a large increase in severe infections and even pernicious cases, *i.e.*, along with an increase in the number of cases admitted there would necessarily be *pari passu* an increase in their severity. How far one is justified in such a view as the above can only be shown by more extended enquiry. But as will be seen there are other considerations which point to the conclusion that relapses play a large part in the malaria of the convict community.

## FREQUENCY OF READMISSION.

46. In the last section it was seen that a very large proportion of cases admitted to hospital remain in the wards only a very short time. It becomes important to know to what extent these admissions are independent of one another. Analysing 647 admissions for fever during the months January to March 1909 the following information was obtained:—

Admitted for fever in the period	.	.	.	.	.	.	.	.	647
Showing 1 readmission	.	.	.	.	.	.	.	.	113
"    2    "	.	.	.	.	.	.	.	.	25
"    3    "	.	.	.	.	.	.	.	.	5
									178
									178

The number of readmissions must necessarily be somewhat higher than this because the period before the chosen time was not taken into consideration.

In April 1909 out of 366 admissions for fever to Haddo Hospital 155 had been in hospital for fever during the previous three months. The medical history sheets of convicts also shews that frequent readmissions are common.

47. The frequency of readmission is important because if, as I shall shew is probable, much of the fever in the Andamans consists of relapses, it indicates the desirability of a policy of, as far as possible, *curing* each case admitted. At present I do not think that treatment of this thorough kind is attempted. How far thorough quinine treatment of cases could be carried out and what the effect of this measure would be requires trial to ascertain.

## ORIGIN OF INFECTION RESPONSIBLE FOR RELAPSES.

48. Even assuming that much of the fever among the labouring convicts is due to relapses, such evidence as can be obtained is against the view that infection contracted before arrival is to any appreciable extent responsible. Only convicts passed as fit are in the first place transported. The examination of 96 new arrivals in the quarantine camp shewed only one case of enlarged spleen and five cases with any appreciable degree of anæmia. Among 48 men examined in the Central Jail (first six months of transportation) none shewed enlargement of the spleen. In the next section it will be seen that the average weight of the spleen of convicts who die at various periods after coming to the Andamans undergoes an increase during the first three or four years rising from an average weight of 12 oz. to 16 oz. or more. All these observations point to the fact that there is a sufficiency of fresh infection

among the convict community in the Settlement to form the basis on which such relapses as occur are founded.

### VII.—The death rate.

49. The death rate per thousand for a number of years among *new arrivals, labouring convicts, and self-supporters* is given in the following table taken from the administration report for 1904-05.

YEAR.	New arrivals.	Labouring convicts.	Self-supporters.
1888 . . . . .	18·7	34·3	19·6
1889 . . . . .	81·8	26·9	21·7
1890 . . . . .	34·8	34·2	21·5
1891 . . . . .	48·6	46·3	12·9
1892 . . . . .	51·2	54·9	24·9
1893 . . . . .	41·5	31·3	14·7
1894 . . . . .	18·1	28·8	24·9
1895 . . . . .	36·2	33·7	13·0
1896 . . . . .	16·7	27·6	9·7
1897 . . . . .	22·0	28·4	13·6
1898 . . . . .	23·4	26·4	19·8
1899 . . . . .	67·7	39·1	14·9
1900 . . . . .	47·7	37·8	22·6
1901 . . . . .	41·9	37·7	15·7
1902 . . . . .	101·5	32·7	14·9
1903 . . . . .	66·3	27·1	21·5
1904 . . . . .	96·8	27·5	18·2

It will be seen that in past years the rates are especially high among new arrivals.

A more detailed statement for certain recent years taken from the administration reports is given below.

Length of residence.	Average number of convicts.			Number of deaths.			Death rate per mille.		
	1906.	1907.	1908.	1906.	1907.	1908.	1906.	1907.	1908.
Under 6 months . . .	699	309	382	17	2	3	24.3	6.4	5.2
Over 6 and under 12 .	1,303	837	694	39	5	3	29.9	6.0	4.3
Over 1 year and under 2.	1,566	1,223	764	69	28	14	44.0	22.9	18.3
Over 2 years and under 3.	1,391	1,279	1,192	68	33	29	48.8	25.8	24.3
Over 3 years and under 7.	3,094	4,435	4,791	156	97	124	50.4	21.8	25.9
Over 7 . . . . .	6,303	6,317	6,202	210	175	202	33.3	27.7	32.6

In these years therefore the highest rates are not among new comers but in convicts who have been a number of years in the Settlement. Without more elaborate enquiry than I was able to undertake it is not possible to do more than surmise that the change is due to the increasing attention given to the medical aspect of the treatment of convicts, especially the attention now given to the conditions affecting new arrivals.

#### PART PLAYED BY MALARIA IN THE DEATH RATE.

50. From what has been said regarding the effect of malaria on the sick rate it might be expected that in the death returns this disease would also figure largely. Such is not the case as will be seen from the following statement :—

#### NUMBER OF DEATHS FROM VARIOUS CAUSES.

	1903.	1904.	1905.	1906.	1907.	1908.
Malaria . . . . .	32	62	51	48	22	31
Dysentery . . . . .	97	111	187	72	45	61
Phthisis . . . . .	110	114	93	89	75	94
Pneumonia . . . . .	65	39	68	72	62	57
Other causes . . . . .	75	100	103	73	91	94
Percentage of deaths due to malaria . . . . .	8	14	10	13	10	9

It will be seen that whilst malaria forms from 50 per cent. to 70 per cent. of the total admissions to hospital it is only responsible in the records for from 10 per cent. to 14 per cent. of the deaths.

51. That malaria should have so small a direct effect upon the death rate is in keeping with what has already been said regarding the comparative mildness of the average attack of this disease among the convicts. It seemed probable, however, that the real effect of malaria in enhancing the death rate is greater than is indicated by the number of deaths directly due to this disease.

To determine the existence and nature of any such indirect effect the records of autopsies were examined. These are of special value in the Settlement since with very occasional exceptions an autopsy is made upon every case of death among the convicts.

These records shew conclusively that as regards the returns made under dysentery, phthisis and pneumonia, diseases to which the bulk of deaths are ascribed, there is no question but that death has been due in the great majority of cases to the disease returned. Nevertheless one was impressed with the much greater importance of "Pneumonia," as a cause of death than is gathered from a perusal of the tabulated statistics.

52. The number of deaths returned as pneumonia in the *post-mortem* records of the three large hospitals Viper, Haddo and Bamboo Flat are shewn in Table XII.

TABLE XII.—RETURNS FOR DIFFERENT CAUSES OF DEATH, 1907 TO 1911.

	Pneumon- ia	Dysen- tery.	Phthi- sis.	Ma- ria.	Fever with jaundice.	Other.	Total.	Percentage of Pneumonia.	Percentage of Dysentery.
								Per cent.	Per cent.
Viper	123	59	30	29	18	121	380	32	16
Haddo	105	146	44	23	6	144	468	22	31
Bamboo Flat	75	68	264*	34	19	61	...	...	...

\* Includes deaths in phthisis ward for whole Settlement.

In addition to these there are however a number of deaths due to the common sequelæ and concomitants of pneumonia which should also be included under this heading. Such cases were most of those returned as gangrene of the lung, pericarditis, or pleurisy. Empyema is also obviously most likely to be a sequela of lobar pneumonia. Not infrequently cases returned as remittent fever and acute diarrhœa (often admitted in extremis) show hepatisation of the lung and are probably often primary pneumonia cases. Cases returned as dysentery also not infrequently show hepatisation of the lung and in such cases it is probable that pneumonia was the actual cause of death. At Viper such cases would increase the rate for pneumonia by about another 25 per cent.

(Out of 131 consecutive records of autopsies 53 were cases returned as pneumonia and another 14 were cases with *post-mortem* evidence of this disease or due to its common sequelæ). The total effect of pneumonia as an actual cause of death is therefore very considerable.

Viper draws its patients from what is undoubtedly the most malarious part of the Settlement (Western District). Haddo, on the other hand, draws most of its cases from the comparatively non-malarious stations about Aberdeen. It will be seen that the proportion of deaths from pneumonia in Viper is remarkably high compared with those for any other disease whilst at Haddo dysentery becomes a more prominent cause of death.

The following tables (Tables XIII and XIV) give the average weight of the spleen for different diseases and areas compiled from the *post-mortem* records. It will be seen that the size of the spleen in pneumonia deaths is even greater than that in cases returned as deaths from malaria (mostly chronic infections). This disease in fact holds quite a unique position in regard to the increase in weight of the spleen.

That this increase in the average weight of the spleen is not an effect of pneumonia *per se* is shewn by the figures given in the last lines of the tables. These are the rates shewn in cases of lobar pneumonia in the records of the Calcutta Medical College obtained from information very kindly abstracted for me by Major L. Rogers, I.M.S.

TABLE XIII.

		Pneumonia.	Dysentery.	Phtisis.	Chronic malaria.	Fever with jaundice.	Other causes.
VIPER . .	No. of cases .	112	46	29	27	18	108
	Average weight spleen in ounces.	20.1	12.8	14.2	17.3	17	15.4
HADDO . .	No. of cases .	75	111	34	14	6	112
	Average weight spleen in ounces.	24	12.9	10.7	22.1	19.5	14.6
BAMBOO FLAT .	No. of cases .	70	67	196	34	17	59
	Average weight spleen in ounces.	22.9	11.5	14.3	21.4	15.6	16.4
CALCUTTA .	No. of cases .	60	...	...	...	...	...
MAJOR ROGERS	Average weight spleen in ounces.	10.7	...	...	...	...	...

TABLE XIV.

		Under 1 lb.	Over 1 lb., and under 2 lbs.	Over 2 lbs., and under 3 lbs.	Over 3 lbs.
Viper . . .	{ Pneumonia . . .	46	51	12	3
	{ Dysentery . . .	34	9	2	1
	{ Phthisis . . .	21	6	1	1
	{ Malaria . . .	13	11	3	0
	{ Other causes . . .	74	34	15	3
Haddo . . .	{ Pneumonia . . .	15	39	16	5
	{ Dysentery . . .	73	37	0	0
	{ Phthisis . . .	28	6	0	0
	{ Malaria . . .	2	9	0	2
	{ Other causes . . .	62	42	12	3
Bamboo Flat . . .	{ Pneumonia . . .	21	30	17	2
	{ Dysentery . . .	54	10	3	0
	{ Phthisis . . .	125	65	3	3
	{ Malaria . . .	14	12	7	1
	{ Other causes . . .	40	28	5	1
Calcutta . . .	Pneumonia . . .	45	12	1	2

It is difficult to see what other conclusion can be drawn but that there is a close association between malarial infection and the incidence of fatal lobar pneumonia. My clinical experience in the Settlement upholds this view for among the cases admitted to hospital with parasites (Table II) two later developed a fatal pneumonia. One other severe malaria case was admitted for bronchitis.

Neither dysentery nor phthisis shows any enhancement of the average spleen weight and the former disease even shows a distinct lowered average weight, a fact which is explained in the next section.

#### EFFECT OF DIFFERENT DISEASES IN RELATION TO LENGTH OF RESIDENCE.

53. The results of a determination of the average spleen weight for different diseases at different periods of residence are given in Table XV.

TABLE XV.

Convict numbers in groups of thousands.	Over 30,000.	28,000 to 30,000.	26,000 to 28,000.	21,000 to 26,000.	15,000 to 21,000.	10,000 to 15,000.	1 to 10,000.
Approximate time of deportation.	1908 onwards.	1906 and 1907.	1904 and 1905.	1901 to 1904.	Prior to 1901.		
Number of autopsies, 1910 and part of 1911.	73	81	55	76	78	71	22
Average weight of spleen of autopsies in 1910 and 1911 (in ounces).	14	15	16	19	19	18	14
Percentage of deaths due to Pneumonia.	11	24		28	32	27	15
Percentage of deaths due to Dysentery.	38	27		7	9	4	0
Percentage of deaths due to Phthisis.	15	15		25	23	28	31
Percentage of deaths due to other causes.	36	34		41	36	41	54
Number of autopsies in 1909.	26	43	35	43	36	27	7
Average weight of spleen in autopsies in 1909 (in ounces).	12	16	17	18	20	24	16
Percentage of deaths due to Pneumonia.	0	14		23	27	16	26
Percentage of deaths due to Dysentery.	61	31		20	9	5	13
Percentage of deaths due to Phthisis.	11	18		22	24	24	22
Percentage of deaths due to other causes.	28	37		35	40	54	39

This table is compiled on the basis of the serial numbers which are given to convicts on their arrival at the Settlement. These numbers enable one to judge of the length of residence with sufficient accuracy for our purpose.

It will be seen that the spleen weight in the case of those dying increases during the first few years rather rapidly, and then more slowly to a maximum of about 18 oz.

It will also be seen that whilst pneumonia, phthisis and other causes reach their maximum percentage in those who have been a number of years in the Settlement, dysentery exhibits a remarkable relative prevalence in the first few years.

Pneumonia especially shews a small relative effect on new comers and a maximum effect in those who have been about ten years in the Settlement. This corresponds with the period of greatest average spleen weight.

Early comers are chiefly resident in the comparatively non-malarial Aberdeen area and the low average spleen weight in dysentery may be partly at any rate due to this fact. Phthisis, however, shews a delayed incidence as great as that of pneumonia though the average spleen weight is only about half what it is in this latter disease.

The relation of pneumonia to malaria therefore seems quite a definite one. Judging by the results of the enquiry dysentery shews very little relation to malaria.

#### SOME SPECIAL DISEASES THE CONNECTION OF WHICH WITH MALARIA IS UNCERTAIN.

54. In the annual sanitary reports of the Settlement mention is frequently made of a fatal fever of short duration associated with jaundice. Unfortunately no cases of this fever occurred during my stay in the Andamans and the following information regarding its nature are based only on information contained in hospital reports and upon some films of blood and organs kindly furnished me by Major Woolley, I.M.S.

The symptomatology of the disease is that of a severe fever of short duration associated with jaundice and most frequently fatal. It occurs especially among the self-supporters of certain villages, the most notable being Port Mouat and old Namunagahr (very malarious site since abandoned). It has also occurred at Dundas Point presumably among labouring convicts.

Cases picked out for me from the admission books as special cases by the Senior Medical Officer had the following seasonal distribution. In 1907 two cases occurred in July, in 1908 four cases occurred respectively in July, August, October and November. In 1909 one case occurred in June, three in July and one in August, September and November, respectively. Two cases had occurred in July 1911 shortly before my arrival. It will be seen that the local seasonal distribution closely follows that of malaria. But the average spleen weight in these cases works out at 13.7 oz. which is not above the average.

In films of the organs of one case, which had deteriorated greatly in the moist damp atmosphere, I found a small amount of what might have been malarial pigment, but the appearances were not those of a fatal and acute malaria.

Similarly in some excellent blood films of a recent case (a European living near Port Mouat) sent to me by Major Woolley, I found after long search only one small malignant tertian ring and no evidence of a severe and fatal malarial attack.

The question of Blackwater fever occurred to me but in the notes accompanying the last mentioned case it is definitely stated that hæmoglobinuria was not present. Nor could I find any of the usual evidences of this disease (engulfed red cell shadows, etc.)

It is useless to theorise regarding this disease the nature of which still requires elucidation.

55. Cases of severe anæmia resulting in many cases in death are not uncommon among the labouring convicts. The nature of these cases is often very uncertain. They have been returned as malarial anæmia. The average weight of the spleen in such cases is not high (13·3 oz.) and in one typical case seen by me *post-mortem* this organ was normal in size and appearance, and there were no parasites or malarial pigment in the organs.

Prolonged search in four severe cases in hospital failed to shew malarial parasites and the leucocyte values were not those of malaria. A very characteristic feature of the blood picture in all four cases was the large size of the red cells and the presence of immense polychromatic cells such as I have not seen either in malaria or following Blackwater fever. The nature of these anæmia cases is uncertain and their relation to malaria doubtful.

#### GENERAL CONSIDERATIONS ON THE DEATH RATE.

56. It seems clear that whatever effect malaria may have in an indirect way upon the death rate among the labouring convicts it is by no means the essential reason of the high mortality. The death rates for phthisis and dysentery diseases which we have seen do not shew any special relation to malaria, give rise to about half the total deaths. When the amount of care taken in regard to feeding, housing and sanitary matters is considered it seems very probable that the most fundamental cause of a high mortality is the profound effect upon men of imprisonment and transportation. In addition there is the fact that a very large collection of men have been congregated under very artificial conditions within a small area.

The problem of malaria among the labouring convicts from what has been shewn in this report would seem to be bound up very closely with the general

conditions affecting the health of the community. Over and above any direct attack made upon this disease there is therefore the necessity of attending to everything affecting the general condition of the convicts.

Such a view is important since it enables one to see that an abundant dietary and comforts are not altogether a matter of mere luxury, but under peculiar conditions may be a medical necessity if a reasonable death rate among the community is aimed at. Economy under these circumstances should not be short-sighted and a saving made on a dietary, estimated to be just sufficient, may well lead to ultimate loss when hospital expenditure and labour efficiency with all that this means is taken into account.

### VIII.—Summary and conclusions.

The observations recorded in the preceding sections enable some very definite conclusions to be drawn regarding malaria in the Andamans.

#### MECHANISM OF TRANSMISSION.

57. The chief carrier of malaria in the Settlement is *Nsm. ludlowi*, a species which breeds in and about salt swamps and was not found at a greater distance from salt or brackish water than half a mile.

The species of parasite proved to be carried by this anopheles was malignant tertian. It is probable as happens with other species that it carries all forms of the parasite.

Whether any part is taken in the transmission of malaria by the other common species *Nsm. rossi* and *My. barbirostris* is doubtful. In any case the latter species could only be an important carrier within the forest. The mere clearing of the land has made it unimportant even in regard to numbers.

58. Owing to the distribution of *Nsm. ludlowi*, malaria in the Settlement is confined to a belt around the margins of the harbour and is absent or nearly so from villages more than half a mile from the sea coast or the salt swamps associated with this. This freedom from malaria is seen even in inland villages situated on the margins of swamps, amidst rice-fields and near jungle.

In the case of some villages malaria was found in the portions lying nearest the sea but not in the inland portions.

59. The endemicity even within the malaria belt is not strikingly high and only one large village (Port Mouat) showed a spleen rate of over 50 per cent.

60. This moderate endemicity is associated with a moderate prevalence only of anopheles.

Suitable conditions for breeding were unlimited but fish of the genus *Haplochilus* were very common and were found in all waters but those of a very temporary nature.

61. The predominating type of parasite among the children in the villages was simple tertian. Among convicts admitted to hospital and among the convalescent gang quartan infections formed 50 per cent. or over. The carrier was the same and there is little reason to doubt that the quartan parasite predominated in the case of the labouring convicts because circumstances favoured relapses whilst actual transmission of the disease was not very active.

It is interesting to note that though infection with malignant tertian at the time of my visit was very little in evidence yet the only two infected anopheles encountered were infected with this type of parasite.

62. There is some reason to believe that proportionate prevalence of the different forms of parasites in any community is dependent upon—

- (a) Activity of transmission (numbers of anopheles carriers);
- (b) Factors increasing or diminishing the number and continuance of relapses.

Malignant tertian (producing gametes) most abundantly increases whenever transmission is active, *i.e.*, the numbers of anopheles are high. Quartan, producing few gametes but peculiarly prone to relapse and to remain for long periods in the blood, relatively increases when transmission is low but factors favouring relapses high. Simple tertian is an intermediate form able to assert itself most when transmission is moderate and the antagonism to relapses not too high (native children as against well fed Europeans who suffer most from malignant tertian due to fresh infection).

It remains to be seen whether the frequency of relapses at different periods after the original infection does not differ in the case of different parasites, still further enabling us to explain the prevalence of different species of parasite under any given conditions.

#### MALARIA AMONG THE LABOURING CONVICTS.

63. In spite of the moderate endemicity of malaria in the Andamans the labouring convicts suffer greatly from malaria. This high prevalence of the disease is chiefly displayed in mild and frequent attacks associated with a good deal of chronic ill-health of an indeterminate kind. It is very probably that much of this is the result of relapses, not as a rule re-infection.

64. There is a fever season during which the admission rate reaches from 2 to 4 times that present in the healthier season. This season corresponds almost exactly in its onset with that of the rains. It appears to be an almost

exact parallel to the conditions at Panama which Deeks and James explain by ascribing the fever season mainly to relapses.

65. The direct effect of malaria on the death rate as shewn in the returns is small. The bulk of the deaths are due in order of frequency to phthisis, dysentery, and pneumonia. Pneumonia is definitely associated with malarial infection and its incidence among the convicts in the unhealthier western district assumes especial importance.

66. Any relation of malaria to phthisis and dysentery is not easily traced. It is possible that the same causes which lead to a high prevalence of these diseases are also at work in increasing the prevalence of malaria. (Mental effect of transportation, etc.)

67. Under the conditions present among the labouring convicts (moderate fresh infection with a high prevalence of relapses and continued infection) everything relating to food, clothing, shelter and the conditions of labour are of immense importance.

68. So far I was able to judge the care taken of the convicts and the amount of thought and care expended upon their proper feeding, etc., is very noticeable. Also the medical arrangements are excellent. If improvements are possible in these matters they are of a kind that can only be brought about as the result of careful scientific investigation of details as they affect individual convicts. (*Vide* Report by Dr. Bentley and myself on conditions among labour on tea gardens).

69. The treatment of cases of malaria in hospital for malaria is nevertheless deficient. This is partly due to the short periods of detention in hospital and partly to the absence of a policy of thorough and effective treatment of all admissions for fever, a policy the rationale of which depends upon the relative importance of relapses and fresh infections among this community. The relative importance of relapses has been clearly shown in this report. It has also on general grounds been previously pointed out by Major Waters.<sup>9</sup>

## IX.—Recommendations.

### SELF-SUPPORTERS AND FREE POPULATION.

70. In regard to many of the villages occupied by self-supporters and free settlers very little action from the point of view of malaria is required.

Where a village is malarious there is no doubt that the proper procedure is to move it either at once or gradually to a malaria free site. This has in some cases actually been done in the past, *e.g.*, Namunagahr, a village formerly situated close by a swamp but now on an elevated site some distance from the old one.

Since the inhabitants are directly under the orders of Government (there are no very malarious free villages) the only difficulty is that of arranging for cultivable land. In this respect the further opening up of areas in the direction of Templegunj where malaria is at a minimum, would seem to be a very desirable procedure. Such an extension has been already foreshadowed in the Lyall and Lethbridge Report on the working of the Penal Settlement of Port Blair.<sup>10</sup> In this report, dated 1890, Major Lethbridge says :—

“Hitherto the smaller Islands and the coast have been supposed to be the most salubrious parts of the settlement, but from what I saw of the appearance of the self-supporters in Hobdaypur, Tusanabad and even in the newly cleared location of Cadellgunj, I came to the conclusion that it is more than probable that the stations in the interior after they have been cleared and occupied for some time will be found more uniformly healthy. Information on this point will be very valuable and should be obtained without delay.”

Now that the reason for this greater healthiness of the inland areas is clear, it is even more desirable that such a unique opportunity as the possibility of malaria free sites should, where possible, be made use of. Even without going so far afield, it may often be possible by giving consideration to the habits of *Nsm. ludlowi* and the known facts regarding the distribution of malaria in the Settlement, to choose sites altogether or relatively free from malaria.

The village of Port Mouat would seem to be one of the first requiring action of this kind.

#### LABOURING CONVICTS.

71. The question of malaria among the labouring convicts is much more difficult and it is necessary to consider the matter from several standpoints.

72. *Change of site of barracks.*—It is obvious that to do away as far as possible with chances of re-infection by moving stations to really healthy sites rather than sites that simply *appear* salubrious would be an excellent step where possible. Under conditions at the Settlement it is perhaps doubtful whether any extensive movement of this kind could be made. Nevertheless the site of some of the smaller stations where malaria is rife might be arranged for. The removal of the station at Port Mouat, situated as it is a few hundred yards only from the most malarious village in the Settlement, is certainly called for. Before any such change is determined upon the most exact observations should be made as to the conditions, and a limit of at least half a mile from salt swamp or the coast made the first essential.

73. *Anti-mosquito operations.*—In most cases the treatment of salt swamps would seem to be restricted to filling them up. In cases where the area to be

dealt with was small and close to important stations this might be undertaken. Such a case might be the present Female Jail which is very malarious and situated near a comparatively small swamp. Whether the swamp should be filled or the Jail moved would depend upon the relative cost of the two measures. I was led to understand that it would be easier to move the Jail, but whether this would actually be so or not I do not know.

Ordinarily the fact that most of the water of the Settlement is free from larvæ, or very nearly so, and that the rainfall is heavy would make this method of combating malaria in the Andamans not one to be recommended without some special object in view.

74. *Dietary*.—As previously stated there is already in existence a very carefully thought-out system for ensuring that as far as possible the convicts get a good and sufficient dietary and that as much as possible is done to prevent unnecessary hardship. But the immense importance of such matters under the peculiar circumstances of this community make it desirable that improvement in every possible detail should be energetically pushed and the importance of a sufficient dietary above all never lost sight of. In this respect it is only fair to mention that the Senior Medical Officer drew my attention to a number of instances where improvement was under consideration, and that he had already himself undertaken observations of the close and detailed character which alone will enable true improvements to be instituted.

At present there is a system by which convicts after a certain number of years instead of receiving cooked rations draw dry rations and make their own arrangements.

During the short period of my stay which left me little leisure for such a purpose, I was unable to investigate adequately the so-called "Talabwala system." I gathered however that the actual working out of the system as it affected convicts was much more complicated than appeared at first sight and it is very desirable that its actual working should be very closely investigated so that the system may be condemned altogether, modified, or exonerated from blame on a real basis of knowledge. Most of those who have spoken about it to me condemned the system. It is possible, however, that it has certain good points even if some of these are "irregularities." Its greatest danger is not necessarily its effect upon the Talabwala convict but that upon the whole community.

The most suitable type of barrack and details of administration do not come within the scope of the present enquiry. From a malaria point of view the most important considerations are the avoidance of cover for adult anophelæ by well-built, well-ventilated barracks thoroughly and frequently whitewashed. In this respect the keeping of the interior, eaves, etc., whitewashed is probably a measure of importance. To what extent "protection" is possible is doubtful.

75. *Quinine prophylaxis and treatment.*—As noted in Section VII the effective treatment, and, as far as possible, *cure* of all cases of m̄alaria admitted to hospital has already been advocated. It is possible that in addition some arrangement for the more general distribution of quinine on a sound basis could be instituted among those communities that are found especially infected.

The quartan parasite is very sensitive to quinine administered at the right time. Moderate doses of quinine at frequent intervals would therefore seem to be the form of administration indicated.

In conclusion I have to acknowledge the very substantial help given to me by Major Woolley, I.M.S., the Senior Medical Officer of Port Blair and by others in the Settlement. I am especially indebted to Mr. A. Brown, Divisional Officer of the Western District, whose constant help and assistance enabled me to visit almost all the villages in the Settlement.

I am also indebted to Major L. Rogers, I.M.S., for very kindly furnishing me with the abstracts of *post-mortem* records utilised in the section dealing with the relation of pneumonia incidence to malaria.

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Salt Swamp, Andamans. Home of *Nyssomyzomyia ludlowi*.

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