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THE SEASONAL PREVALENCE OF ANOPHELES AND MALARIAL FEVER IN LOWER BENGAL; AND THE PRACTICAL APPLICATION OF THE MOSQUITO THEORY. (One Chart.)

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THE momentous discovery of the part played by *Anopheles* in the propagation of malaria necessitates careful local inquiries into the prevalence of this genus, in order to ascertain how far the different methods of lessening the amount of malaria which have recently been proposed can be profitably applied to the circumstances met with. In no country are such studies more essential than in India on account of the radical differences in the topographical and climatic conditions of different provinces of this vast and densely populated country, ranging from the waterless deserts of Sind to the steamy, waterlogged marshes of Lower Bengal. During the past year I have systematically studied this question in the last-named province, which is a home of malaria, where it is prevalent at all times of the year, and which presents most exceptional difficulties in the way of preventive measures. During the last few months I have travelled many hundred miles as Deputy Sanitary Commissioner, so have had exceptional opportunities of studying the problem, and now desire to put my conclusions on record, especially as some of the facts are not altogether easy to explain on the exclusive mosquito theory, although the experiences of others may possibly throw some light on them. The present inquiry was commenced at the beginning of 1900, when, although it was shown that malaria could be carried by mosquitos, it was not so certain that this is the only way in which the disease could be produced, as now seems likely to prove to be the case. At one time I was inclined to attribute considerable importance to the great divergence between the maximum seasonal prevalence of *Anopheles* (chiefly *A. rossii*) and of malarial

fevers; especially in view of the diminished incidence of malarial fever, as judged by the percentage of enlarged spleens, in areas supplied with filtered water, as compared with similarly situated areas which were without filtered water, to which I have elsewhere drawn attention[1]. However, in view of the accumulation of evidence during the past year in favour of the mosquito theory, due allowance for defects in our knowledge of the life-history of different varieties of mosquitos must be made before any facts which appear to be opposed to the new theory are allowed any great weight, and those about to be recorded may be more easily understood as our knowledge of these insects increases.

The Physical Characters of the Area investigated.

The great difficulty in the practical application of the new knowledge to lessening malaria in Lower Bengal can only be appreciated when the nature of the country is understood. The vast area comprised in the deltas of the Ganges and Brahmaputra rivers, with its millions of inhabitants, is so low-lying that a great part of it is under water during the rainy season, when the numerous villages placed on any slightly elevated spots, often on the high banks of the network of small rivers, can only be reached by boat, while between them stretch interminable rice-fields, forming after the subsidence of the floods innumerable pools which it is quite impossible to either drain or treat with culicides. The freer distribution of quinine is the only practical remedy here. Unfortunately the conditions in small towns are only slightly more favourable on account of the innumerable tanks and smaller excavations in which they abound, due to the fact that all the houses are constructed on raised earth platforms, which can only be made by excavating the earth from the surrounding level ground. Thus it comes about that a town of some 3000 inhabitants will as a rule have over 100 tanks, and not infrequently a still larger proportion, in addition to a very much larger number of smaller excavations. Nor is it possible to fill up these tanks without digging others to supply the earth. The importance of this fact lies in the discovery which I made last year, that, contrary to even the recent statements of Major Ross[2], tanks form a most important breeding place for *Anopheles*, and are indeed the most important one during the greater part of the year in the towns of Lower Bengal, as I shall show presently. This fact having been early discovered, an area of one-sixteenth of a square mile, containing 32 tanks and several

smaller pools and drains, was selected for regular examination for a year in order to study the relationship of the variations in the number and distribution of the *Anopheles* larvae and the prevalence of malaria, as indicated by the number of cases of malarial fever treated at the dispensary which supplies the medical wants of this part of the town. The place chosen is a very small corner of Calcutta itself, and is low-lying and very waterlogged, although the percentage of cases of enlarged spleen was low, apparently on account of the water supply being filtered. The area may be regarded as fairly typical of Lower Bengal towns, but somewhat more unfavourably situated than the average, and much more so than the European quarter of Calcutta.

The Seasonal Prevalence of Anopheles and Malaria during the Year.

The results of the year's inquiry are shown in the accompanying chart, the upper curve representing the weekly number of cases of malarial fever treated at the local dispensary. Below this curve the rainfall is graphically shown, while above it the results of the monthly mosquito hunt are briefly inserted, and at the bottom of the chart the curves of the mean weekly maximum and minimum temperatures are given. The marked and steady rise of the fever rate three weeks after the onset of the rainy season early in June is very evident, as is the continuance of the fever at a high rate through the rains and the following two months up to the middle of December, with an abrupt fall during the latter half of that month. No less definite is the longer season of low fever prevalence, which lasts from the middle of December throughout the rest of the cold weather and the whole of the hot season and the first two or three weeks of the rains in June. In February 1901 there was a slight secondary rise, but this did not occur in the previous year, and is not a constant feature. The temporary fall in the third week in September was due to floods preventing people attending the dispensary. The returns of the number of cases treated in hospitals in many parts of Lower Bengal show the same seasonal curve of intermittent fevers, varying but slightly in different places. The exact weeks in which the main rises and falls occur vary with the onset and cessation of the rains. Thus an examination of charts of the fever rate, rainfall, and temperature variations over a series of years in an important suburb of Calcutta shows that when the rains set in early and end early the rise and fall of the fever curve is also proportionally early in both its rise and fall, and *vice versâ*, so that the curve of the accompanying

chart may be fairly taken as typical of Lower Bengal in general, and of the neighbourhood of Calcutta in particular. Another point which must be mentioned here, as it will be alluded to again, is that, in the districts round Calcutta at any rate, the fever curve always rises with each break of a week or more in the rains during the monsoon, and the unhealthy years are those in which such breaks are frequent, quite irrespectively of the total amount of the rainfall.

Turning now to the variations in the prevalence of the *Anopheles* larvae, from which the adult insects must necessarily be derived, we are at once struck by the fact that their maximum prevalence is in the hot weather months of from March to May, when they are present in enormous numbers in the tanks, the climax being reached in the last-named month, when no fewer than two-thirds of the tanks were found to be infested, and in several of them, including one measuring 350 yds. by 70, the leeward end was covered with a scum of many million larvae and pupae in all stages of development. On the other hand, all the small pools and drains were dried up during this season with the exception of three in March. Yet these three hot weather months are precisely those in which malarial fevers are at their minimum, and in which those few cases which are met with are found to be of the chronic relapsing variety. With the onset of the rains in the middle of June *Anopheles* larvae were much less readily found, only being detected in one-sixth of the tanks examined during this month. At first I thought that this might be due to their being scattered by the rain, but searches after a few days' dry weather showed them to be equally scanty. Another change was the filling up of some previously dried-up pools, in four out of seven of which the *Anopheles* larvae were found; but the net result was a great decrease of the total number of larvae in this area, the diminution in the tanks being very many times as great as the slight increase in the few small pools. In July the conditions just mentioned were accentuated, the larvae being only found twice in a large number of examinations of the tanks, even during a marked break in the rains; while on the other hand on the 22nd of this month out of 14 pools, which had by this time filled with water, 10 contained the larvae, as did some roadside drains. Still the total number was very much smaller than in the hot weather months, as all the small pools put together did not contain a tithe of the numbers formerly met with in a single tank. On the other hand, owing more particularly to their presence in the roadside drains, the larvae were somewhat more widely distributed during the rainy season than in

the hot weather. Still as none of the thickly placed houses of the area under investigation were as much as fifty yards from an infected tank this factor cannot have been a very important one.

In this month a break in the rains occurred, advantage of which was taken to see if the cause of the increase of fever which had been noticed to closely follow such an event could be traced, but it was found that after four days out of the fourteen pools which had been found to contain the larvae, all in a very young stage, no less than nine had already dried up, and in only three were larvae still found. It is evident, then, that a break in the rains greatly diminished the already small number of larvae which were to be found during the feverish rainy season, and the increased fever during breaks in the rains cannot be explained by any corresponding increase of the numbers of *Anopheles*, even if the rises did not occur too soon after the cessation of the rain to allow of the necessary passage of the malarial parasite through newly matured insects. On July 29th the pools were again full of water, but only 1 out of 13 contained the larvae.

In August and September no larvae were found in the tanks, but a certain number were found in some of the pools, and the roadside drains also usually contained them, especially those in which grass protected them from the strength of the currents of water. During the latter month unprecedentedly heavy rain fell, 14 inches being registered on the 20th, and 10 more on the 21st, while over 40 inches fell in 7 days. Calcutta was flooded, and the area under examination suffered severely, being nearly completely submerged. It was not until the 27th of the month that I could get to the place, when I failed for the only time during the whole year to find a single *Anopheles* larva. Although all the pools were full of water, they must have been thoroughly scoured out by the torrents.

During October weekly examinations of the area were made so as to be able to closely watch the effect of the flood on both the larvae and the fever rate. The latter reached its maximum during this month, 260 cases being treated, or nearly three times as many as in the hot weather months; but this is usual at the break of the rains. On the other hand the *Anopheles* larvae were at their minimum, with the exception perhaps of the cold weather months, for while the tanks still remained free, most of the pools dried up before any larvae reappeared in them, so that only from 3 to 5 small pools were found containing larvae during this month, the total being smaller than in the few tanks which are infested during the cold weather months.

Further, they were only found in one-third of the drains during the first half of the month, so that the flood appears to have washed away all the larvae, while on the cessation of the rains the pools and drains dried up before many fresh larvae had time to mature.

At the end of November only one *Anopheles* breeding-pool remained (which did not dry up until February) but the larvae began to appear once more in the tanks, although in much smaller numbers than during the hot weather, and they could be found therein throughout the cold weather months, and once more have begun to increase in them with the onset of warmer weather in March, so that there is no season of the year in this balmy climate when these noxious insects do not breed, although they are less prolific in the cold season than in the hot weather.

The numerous observations on the breeding places of *Anopheles* made by me in various parts of Lower Bengal in the course of tours at the end of the rainy season and during the cold weather and early hot weather months yielded precisely parallel results to those detailed above. They may, therefore, be taken as typical of Lower Bengal, which is the most extensive highly malarious tract in India.

The Importance of Tanks as Breeding-places for Anopheles.

The fact that tanks are the most important breeding ground of *Anopheles* in Lower Bengal must be emphasized, especially in view of Major Ross having recently stated that "it is well known that mosquitos do not breed in tanks, possibly because they are eaten by fish." Perhaps he did not examine them during the hot weather months in densely populated areas. My observations on this point have been fully confirmed by Dr Nield Cook, the Health Officer of Calcutta, and others. Further, most of the tanks in which I found them were swarming with fish, while I have already recorded an instance of *Anopheles* larvae being present in tiny shallow pools of a few square yards in extent in spite of small fish being also therein[1]. The disappearance of the larvae from the tanks during the rainy season, their appearance in small numbers in them during the cold weather months, and their rapid increase in the hot season, are alike remarkable. The most probable explanation of these facts appears to me to be that

[1] Nuttall, Cobbett, and Strangeways-Pigg (*Journ. of Hygiene*, vol. I. p. 12) have made similar observations in England.

during the hot weather months the fish lie dormant at the bottom of the tanks, and the larvae can breed in safety, but during the rains they are more lively and rapidly destroy the insects. This is in accordance with what I saw on my rounds, for while no fish were seen to rise in the hot dry weather, in the rains on the contrary the water often appeared to be alive with them, while in the latter half of this season, when no larvae at all were found in the tanks, shoals of young fish were often seen swimming about close to the surface of the water, and these would have made short work of any larvae which might hatch out in the tanks at that season. However this may be, the fact remains that the maximum number of *Anopheles* mature in the tanks during the hot weather, and any plan for destroying these insects must take this point into consideration; and as far as regards Bengal, at any rate, it is not true that *Anopheles* only breed in small pools without fish.

The Divergence between the seasonal prevalence of Anopheles and that of Malaria.

It will have been observed that the data given above relate only to the number of larvae found each month. Although the number of winged insects hatched out at any time will depend on the number of larvae, the number of adult *Anopheles* will also be affected by the favourableness or otherwise of the conditions which influence the length of existence in the winged state. Unfortunately it was impossible to search for mosquitos in the houses of the area under observation on account of the purdah system[1]. My own residence is situated in the most healthy European quarter of Calcutta, *Anopheles* being seldom found there. However, at the same time that my searches for the larvae were made, Major Brown of the Indian Medical Service, who lives in a feverish suburb of Calcutta, made regular observations on the numbers of *Anopheles* in his house, and his results agree closely with my own in showing that while a few of the adult insects were met with in the cold weather months, yet they increased considerably in the hot weather months, when they attain their maximum, and decreased again on the onset of the rains, just as the larvae did, so that the two stages

[1] Under the purdah system the women of a household must not be seen by any European, and advantage is taken of this by natives to prevent the entry of Europeans into their houses for sanitary or even excise purposes unless due notice is given and other formalities complied with.

closely coincided, as indeed Celli also states is the case in Italy. As, further, in Italy the malarial fevers begin to increase in July, and attain their maximum in August, September and October, decreasing again in November and December, just as is the case in Lower Bengal, it might be expected that the prevalence of *Anopheles* would also coincide in the two countries. Turning again to Celli's recent work on malaria we find he states that in Italy new generations of larvae make their appearance in some waters in May, increase in June, and attain their maximum in the feverish months of July and August, and maintain it until the heavy autumn rains wash them out. If the tanks are left out of consideration, and only the pools and drains are considered, then the Italian conditions agree closely with those of Lower Bengal, and no doubt of other parts of India which are affected by the south-west monsoon [3]. This relationship is, however, completely altered by the marked increase in the number of *Anopheles* breeding in the tanks, this increase beginning in March and reaching its maximum in May at the season of minimal fever; decreasing in June, and practically ceasing in July, that is in just the months when malarial fevers begin to increase. I am inclined to think that the influence of the great heat of from March to May is the operative factor, which may act by preventing the majority of the insects which are hatched out in the hot season from surviving long enough to act as effective carriers of the malarial parasite. Certain it is that I have found it more difficult to keep *Anopheles* alive for more than a very few days in the hot weather than in the rainy season. Still the prevalence in the tanks must be taken into account in considering the feasibility of destroying these pests.

The rise of malarial fevers to a maximum in October, at the very time that the number of *Anopheles'* breeding places are decreasing, is probably accounted for by the steadily increasing number of infected adult insects in the houses throughout the fever season. These insects will continue to live as long as the temperature and other conditions are favourable. It is worthy of note that the rapid fall in the fever curve at the end of December occurred three weeks after the minimum temperature fell below 60° F., which is very nearly the lowest point it reaches in this genial climate, so that the diminished fever rate is probably due to the relative coldness being inimical to the local *Anopheles*. It is also remarkable that the rise of the fever curve in February was coincident with an unusual rise of temperature for the time of year, which again may have awakened the hibernating *Anopheles*

to a sense of their opportunities in justifying their name as being harmful. With the exception, then, of the remarkable and important prevalence of the *Anopheles* in the tanks during the hot weather, the other facts with regard to the seasonal distribution of these mosquitos and of malarial fevers respectively agree very fairly well, and are in accordance with recent observations in other parts of India[3].

The Prophylaxis of Malaria in Lower Bengal.

We are now in a position to discuss the application of the various methods of preventing malaria which have been recently proposed on the basis of the mosquito theory. The fact that the highest authorities differ very widely in their advocacy of these measures indicates that, while none of them are perfect in practice, each may have its value in different conditions, and they may be most conveniently dealt with under separate headings.

1. *The destruction of Anopheles.* Very few authorities now consider it feasible to reduce malaria materially by the destruction of *Anopheles*, but as Major Ross is still of the opinion that in the end this will be the cheapest and most effective method[2], it must be considered in the case of towns. The very frequent infection of even large tanks (and those I found infested by *Anopheles* varied between 10,000 and 200,000 square feet in surface area) would require a very large amount of oil or other material to disinfect them once a week throughout the hot weather, as well as a large staff, while the area examined is about one two hundred and fiftieth part of Calcutta, so that the difficulty of dealing with the thousands of tanks within the town and its suburbs would be very great. Unfortunately I found from inquiry that the owners of many of the tanks would not hear of any disinfectants being added to them for fear of harming the fish, so that the task of thus destroying the mosquitos in the tanks is an impossible one. The number of pools during the rains is also enormous, but much might be done in filling them up. More important and difficult to deal with are the open drains which line each side of every road. In the main streets, where they are lined with stone or brick, the current is sufficiently strong to wash away the larvae, but it is quite otherwise with the numberless earth-lined ones in the suburbs, which I found to form the most important breeding place for *Anopheles* during the rainy season, as well as near water stand-pipes in the drier times of the year. Some attempts to disinfect these by weekly applications of tar were made by Dr Cook, but in one instance

which I watched I found that a temporary decrease in the number of the larvae in the treated part, as compared with another part of the drain not so treated, was followed at the end of a week by the reversed condition of more *Anopheles* in the tarred portion, apparently due to numerous small frogs having been driven out by the tar, most of which had been subsequently washed away by the rain. The scores of miles of these drains in such a town as Calcutta will be at least as formidable to deal with as the tanks. It must also be remembered that the experiments of the Committee of the Royal Society [4] have shown that artificial pools become infested with *Anopheles* within a few days, even when there are no breeding places in the neighbourhood, so that it would be of little use to try and destroy the larvae in a limited area of the town, as the breeding places would be very quickly reinfested from the surrounding parts. I regret, then, to have to come to the conclusion that it is not feasible to reduce very materially the number of *Anopheles* in Bengal towns by any practical method of destroying the larvae. Something in this direction can and should be done in the more favourably situated European quarters of our towns, but to attempt at a heavy cost to reduce the malaria of whole towns in this way in Lower Bengal is, I feel sure, certain to end in failure, which would do much harm by creating a prejudice against all measures based on the mosquito theory. Although I would deprecate the expenditure of the large sums that would be necessary to disinfect regularly the enormous and extensive mosquito breeding places in the tanks and drains of Bengal towns as being unlikely to meet with sufficient success to warrant the expenditure[1], yet this is no excuse for not doing as much as possible under the circumstances to lessen the number of breeding pools. The most important measure is to make use of the powers conferred by the municipal Act to make owners fill up small depressions such as will form suitable breeding pools during the rainy season. This I have always enjoined in my municipal inspections, while circulars have been issued in India calling attention to the importance of this simple proceeding, by which some good can be effected. This and any other such measures should be begun before the rains set in. It should also be clearly understood that the above remarks only apply to Lower Bengal, where the conditions are exceptionally unfavourable, while possibly much more might be successfully accomplished in drier

[1] It must be borne in mind that the total income of a Bengal town of 30,000 inhabitants for all sanitary and municipal wants is but some £2,000, so that the necessary expenditure can only be met at the cost of omitting other essential sanitary measures.

provinces, although these will be less malarious than Bengal and Assam. There is one reform which might and ought to be carried out in India, and that is the prohibition of rice-fields within the limits of towns, or within a mile of their boundaries. This measure has been found of value in both Italy and Spain. *Anopheles* have been found breeding in rice-fields in Madras.

2. *The Use of Quinine.* The suggestion of Koch, Grassi, and others to destroy the malarial parasite in the blood of the comparatively small number of persons who carry it during the season of minimal fever prevalence, is worthy of careful trial in places where there is a very marked and prolonged season of absence of new infections, and where the inhabitants are sufficiently intelligent and well to do to understand and carry out the method, and efficient medical supervision is available. The wholesale experiments in Italy will be watched with the greatest interest. Unfortunately none of these necessary conditions are met with in Bengal, where, even during the months of minimal fever incidence, the number of fever cases, mostly no doubt relapses, still form about one-fourth of the numbers at the maximal season, so that the complete use of this method is impracticable in this country. The sale of pice[1] packets of quinine through the post-offices has done much to bring this drug within the reach of the rural inhabitants, but unfortunately they are too poor to use it regularly as a prophylactic, even if they could be persuaded to do so.

On the other hand, in the case of Europeans, I have for some years been strongly in favour of the prophylactic use of this drug during the malarial season or on visiting malarial places, and believe this practice was the main cause of my escaping malarial fever during a year's work in the most unhealthy districts of Assam, investigating the epidemic malarial fever of that province, locally known as kala-azar (black fever), although I never used mosquito curtains on account of the heat. I prefer ten-grain doses twice a week, or for those who are specially susceptible to the drug, five grains every other day.

It is from this point of view, too, that studies of the effects of meteorological conditions on the curve of the incidence of fever are of great value, for on account of the frequency of recurrences of malarial fever secondary attacks must be more common than primary infections, and any data by which the likelihood of a recurrence can be foretold will be an important guide to the successful prophylactic

[1] A pice is equivalent to a farthing of English money.

use of quinine. I have elsewhere pointed out that in places with a low ground-water level during the dry seasons, and where it rises rapidly and fluctuates considerably during the rains, the fever curve rises with each rise of the ground-water and falls with each decline[5]. Again, in Lower Bengal, as well as in other places, such as Lucknow in the North-West Provinces, where there were no such violent fluctuations of the ground-water, the fever curve rises during the breaks in the rains, or under just the opposite conditions to the former case. Such variations of the fever curve must largely depend on causes which predispose to a relapse in persons already infected by the malarial parasite, and a knowledge of these facts will allow of quinine being taken as a prophylactic at the time of heavy rain in the former case, and during breaks in the rains under the latter conditions: a plan which I have repeatedly acted on with, I believe, beneficial results, and whose value is not affected by its discovery being independent of and prior to the establishment of the mosquito theory. The precise explanation of the facts noted is not quite so clear, but breaks in the rains are always most trying on account of the great damp heat, which by lowering the resisting power might easily predispose to a relapse, while in the higher parts of Chotta Nagpur, where I met with the most marked instance of the rise of fever with heavy rain, this was accompanied by a very great and rapid fall in the temperature, sometimes amounting to 30° F. in a few hours, such as might easily cause a recurrence of fever which a timely dose of quinine would prevent or greatly mitigate.

3. *Protection from mosquito bites.* Not much need be said under this heading, as everyone will admit the advisability of using mosquito curtains in malarious places, although it is not practicable in ordinary civilised life to stay within them from before sunset to after sunrise. The protection of houses by wire netting is beyond the means of the poor, and will not be advisable in the case of Europeans except in a few very malarious spots, on account of the great obstruction caused by netting to the free circulation of breezes through the house, which is such an important factor in keeping them from getting stiflingly hot in the tropics, and so rendering life bearable. The application of substances to exposed parts of the body to prevent the insects biting may also be of use, and I have known them successfully applied to keep off swarms of mosquitos when men are sitting up at night over a kill for tiger. Insecticide powders are also being burned with advantage in houses in India for lessening the number of mosquitos.

4. *Drainage operations.* Extensive drainage operations have fre-

quently been carried out in India for reducing malaria, a successful example of which will be found in a paper by Major Dyson, I.M.S., in the Transactions of the first Indian Medical Congress, 1895, p. 283. It is equally important to prevent places being made more malarious by raising the ground-water level through obstruction to surface drainage in the construction of embankments for railways and canals, without allowing sufficient waterway through or under them.

It is, however, only under exceptional circumstances that large drainage operations can be undertaken in India for the lessening of malaria, and Lower Bengal is particularly unfavourably situated for such works on account of the very peculiar circumstance that the water in most of the rivers rises to a greater height than the surrounding country, which must be flooded by them more or less during the height of the rainy season, sufficient drainage being impossible.

But there is another aspect of the question which demands more attention, and that is the condition of the roadside drains in towns and large villages. I have already pointed out earlier in this paper that the unlined roadside drains form the most important breeding place for *Anopheles* in the rainy fever season, while they are most difficult to disinfect. On the other hand, I have never been able to find the larvae in brick or stone-lined drains with a good current of water flowing through them. It is obvious, then, that the lining of the roadside drains in small towns will be an important measure in lessening the number of *Anopheles* breeding in close proximity to the most thickly distributed houses of the place. I have also observed that the larvae are most easily found in such unlined drains as have grass growing in them, especially after heavy rain, the grass evidently affording the larvae considerable protection from the force of the current. The cleaning out of all such drains as cannot be lined at regular intervals during the rainy season will, then, also be an important sanitary measure from this point of view, and these suggestions should be carefully acted on by municipal authorities in Bengal as well as in other places in which such drains are found to harbour the larvae of *Anopheles*.

5. *Segregation measures.* The discovery by Koch in New Guinea, and by Stephens and Christophers in West Africa, of the frequency with which infants harbour the malarial parasite in their blood with little or no symptoms, strongly supports their conclusions that native children are an important source of infection to Europeans living in

their neighbourhood, and indicates the necessity of the European quarter being at some distance from native huts. This, together with the selection of sites for rest-houses at some distance from the nearest village, instead of close to it, should be carried out in India. During a recent tour in a remote part of the Tributary States of Orissa I came across a sub-divisional station which was so malarious that a new site eight miles off was being laid out to which the offices, etc. were to be shifted from the unhealthy spot. I was just in time to get the authorities to make some slight alterations in their plans so as to ensure the native quarter being kept at a distance from the Europeans' houses, and the result will be watched with interest.

There is one other set of circumstances in which the principle of segregation may be of the utmost value, and one too which I was able to recommend and carry out with very great success in 1897 before the discovery by Major Ross of the communicability of the disease through the mosquito, and which I may be pardoned for referring to here. I refer to the epidemic malarial fever of Assam, or kala-azar[6], which I declared as early as 1897 to be a very intense form of malarial fever, slowly and probably indirectly communicable from one person to another in some way which was not quite clear, but which I did not think at the time was transmitted by means of the mosquito, because I felt sure that the vehicle of infection was not water, as was suggested in Manson's original hypothesis. I gave numerous instances of the disease being introduced into a village by a person infected with this particular type of malarial fever, and in which the first people to get it were those living in the same house as the imported case. Ross a year or two later confirmed my views after a short personal investigation of the disease in Assam, and generously gave me full credit in his report for my "boldness in declaring the communicability of paludism," while his brilliant researches have settled the difficulty as to the exact way in which the disease is spread; and now that malaria is known to be actually inoculated by the mosquito, I fully accept this method of infection as explaining the facts with regard to the spread of this peculiarly intense form of malaria in Assam. I have elsewhere described[7] the success of the measures which I advocated for the control of the disease, and have given instances in which by moving out all those who had fever, together with their households, during the cold weather when the disease was at its minimum, several coolie lines remained quite or very nearly free from this very fatal form of malarial fever throughout the following fever seasons. In another instance where

33 inches.

1900. 1901.

Prevalence of Anopheles larvæ in

	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	
Tanks	some infested	half infested	one-third infested	two-thirds infested, several increasing	one-sixth infested with few only	only two infested	nil.	nil.	nil.	one sixth infested	few infested	few infested	few infested	increasing	*Tanks.*
Pools	one infested rest dry	three infested rest dry	all dry	one infested rest dry	4 out of 7 infested	10 out of 14 infested	9 out of 12 infested	nil after flood 6 out of 11 infested	5 out of 7 infested rest dry	two infested rest dry	one infested	one infested rest dry	all dry	all dry	*Pools.*
Drains	all dry	dry	dry	dry	two infested	all infested	all infested	half infested	one-third infested in first half only	all dry	all dry	all dry	all dry	all dry	*Drains.*
General Prevalence	scanty	numerous	numerous	maximum	much fewer but more diffused	more widely distributed	somewhat scanty	somewhat scanty	scanty	scanty	scanty	scanty	scanty	increasing	*General Prevalence*

Prevalence of Anopheles larvæ in

Weekly number of Malarial Fever cases. 72 64 56 48 40 32 24 16 8 0

102 101 83 95 104 183 231 203 260 248 188 107 128 113 Monthly total Fever cases.

Weekly Malarial Fever cases.

Weekly Rainfall in inches. 9 8 7 6 5 4 3 2 1 0

Weekly rainfall in inches.

Temperature Fahrenheit. 95 90 85 80 75 70 65 60 55 50

Maximum.

Minimum.

Mean weekly temperature.

Chart of Monthly prevalence and distribution of Anopheles larvæ, and Weekly variation of Malarial Fever, Rainfall, and maximum and minimum Temperature.

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more than half the households were found to have the infection the remaining healthy ones were removed, and placed, together with a large number of freshly imported coolies, in a new line some three-quarters of a mile from the old one, with equally satisfactory results, none of them becoming infected during the next four years. These measures have in fact been so successful that recently I was unable to get any post mortem material of kala-azar cases from the very gardens which a few years back were having over a hundred deaths a year from this disease. I may, then, fairly claim to have recognised the infectious nature of this virulent form of malarial fever. I moreover successfully carried out measures of segregation two years before the brilliant work of Ross afforded a solid basis for the mosquito theory, and showed that the infection was conveyed through the air, as I thought, and not through water, the mode of entrance being, however, inoculation by mosquitos, and not inhalation through the lungs, which I suggested as the most likely hypothesis at that time. The value of segregation, under special circumstances at any rate, is, then, proved, and when it is applicable it is a most important measure in preventing the spread of malaria, especially in its very fatal epidemic forms, such as the Mauritius epidemic in 1866—67, the Burdwan fever, or as I prefer to call it the epidemic malarial fever of Lower Bengal, of the fifties, sixties, and seventies, of which I have shown elsewhere[8] there is some reason to believe the Mauritius epidemic may have been an offshoot, and the present epidemic malarial fever of Assam, now happily on the wane.

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