engineering operations. In view of the probability that the rice fields in the Umkhrah Valley can produce an appreciable and probably dangerous number of *A. maculatus* from April or May until the end of October, residents of houses situated on the heights above the stream would probably be well advised to protect themselves by the use of mosquito nets at night during these months.

Within the station, however, and especially if the minor improvements which I have suggested in the valley of the Ka Wah Pomdingim and elsewhere are effected, it would appear as if the chances of acquiring malaria in Shillong are so slight as to be negligible and to demand no special personal precautions.

MALARIA ON AMBOOTIA TEA ESTATE NEAR KURSEONG AND THE SUCCESS OF SOME ANTI-MALARIAL OPERATIONS.

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THE malariology of hill-stations is an important subject, for visitors do not go to them to spend their holiday abed with fever. Any contribution, therefore, to our knowledge of the subject may be helpful.

The observations now recorded were made in May 1923 during a visit to Ambootia Tea Estate, Kurseong, about 3,000 feet above sea-level in the Eastern Himalayan foothills. They indicate the salient factors which determine malaria incidence on the estate; and their analysis throws into relief the effect of the anti-malarial operations which had been initiated with uncommon enterprise by the Manager, Mr. A. O'Brien-Webb, at the instigation of the Visiting Medical Officer, Dr. Kingsley-Ward. The nature of the operations was mainly the drainage of swamps and training of streams.

In the course of the work the first point considered was whether the rainfall had anything to do with the malaria-rate. Generally speaking when a malaria-rate corresponds with a moderate rainfall, one would incriminate swamp-breeding anophelines; while if such data have an inverse relationship stream-breeders might be suspected; the reason being that heavy rains scour out the breeding places and so diminish the sources of malarial infection. This has been emphasised by Perry (1914) with reference to the Jeypore hill-tracts.

The estate records which were necessary to decide the point had been in charge of the Medical Officer of the estate and the conclusions submitted are drawn from the analysis of those from 1917 to the present time.

A chart drawn to show the rainfall, the case-returns, and the case-rate (i.e., the number of cases per cent. of population) every year, and also these data computed for the 12-monthly periods from June to May revealed no direct correlation in them; indeed, between the incidence and the rainfall there was a tendency to inverse correlation (Chart 3). There was, however, no doubt about the inverse relationship if the data were compiled for the period January to May of the year, and the inversity was also evident in the June to December period (Charts 4 and 5).

These findings then indicate that the pathophors here are stream-breeders, and this conclusion is supported by the fact that the writer had much difficulty in capturing any stream-breeders after the fall of several very heavy "chota-monsoon" showers just previous to his visit, and that "swamp-breeders" were absent.

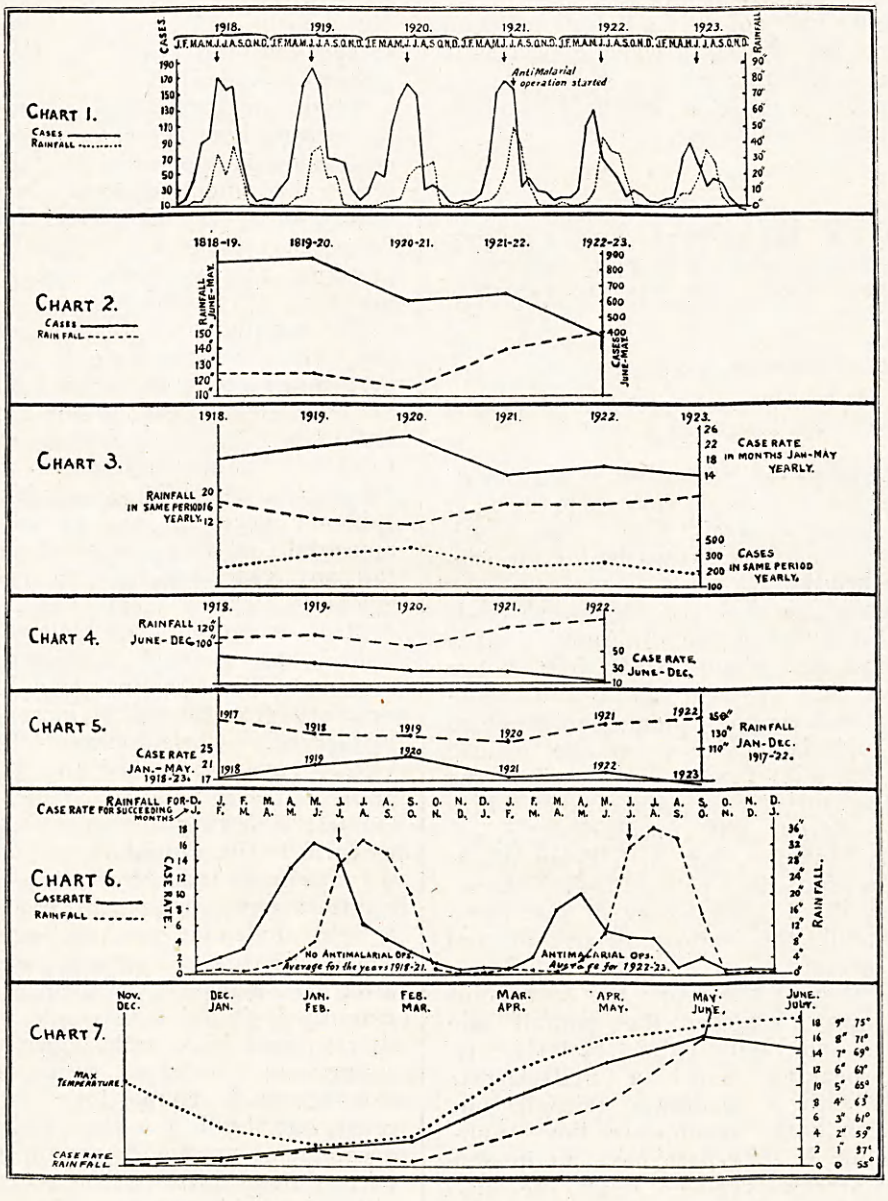
The circumstance of the inversity, within any period, of case-rate to rainfall does not give much scope for predicting the severity of the epidemic season; but a good means of prediction was discovered by charting yearly rainfalls against case-rates for the period January to May following, during which the epidemic becomes well established. It then appeared that the greater the monsoon rainfall any year, the less the case-rate in the epidemic season next year. Marjoribanks (1914), referring to malaria on Salsette Island, has averred the same fact in his statement that "a dry year followed by an ordinary year causes an increase of malaria-incidence." Christophers (1911) and Gill (1922) have recognised the general importance of being able to predict malaria epidemics, in setting forth the factors conducing to them in the Punjab.

Incidentally the fact that on Ambootia Estate a heavy monsoon year is followed by a light epidemic year, proves that on these slopes seepage of subsoil-water for months after the monsoon does not occur to any extent. If it did, one would feel sure that there would be a rich legacy of dangerous spring-water breeders such as *A. maculatus* causing much trouble long after the rains cease, but this is not the case. Probably the decomposed micaceous granite soil here is so porous that water flows away through, almost as readily as over, it.

The relationship between rainfall and malaria was further analysed in Chart 7, where the monthly records from 1917 to 1923 are given. Apart from any question of rainfall-malaria correlation it must be observed in this chart, that subsequently to March, 1922, when Mr. Webb started his anti-malarial operations (as noted above) the improvement of health was immediate and

sustained. The reason for this was probably the fact that the troublesome mosquitoes, being stream-breeders, had been subjected by means of the operations more than naturally to the force of the "chotamonsoon" showers.

The monthly data have been condensed in Chart 6 into two periods, first for 1918–21 and then the years 1922-23 during which anti-



malarial operations have been in progress, but in this chart rainfall has been apposed to the malaria incidence *of the subsequent month* for the reason that the development of the mosquito and its malaria parasite and its incubation in man takes a month or more to complete. A study of the chart and also of Chart 7 which gives the same data on a larger scale (for the early months only),—Chart 7 giving also the temperature records,—leads to the following conclusions:—

(a) In the pre-monsoon period, from November to February inclusive, the malaria case-rate of the succeeding month goes up independently of both the monthly temperature and the rainfall. Probably the slight rise in case-rate is here due to recurrences induced by cold and exposure.

(b) After February until May the same data are very closely correlated;

(c) which proves that the rising rainfall with its tendency to depress the case-rate is counterbalanced by some other factor, and this is probably, at this time of year, the rising temperature.

(d) After the monsoon breaks, the great increase of rain in June and July, is responsible

for a rapid decline of malaria in July and August;

(e) which proves that the May brood of mosquitoes begins to die out by July, and that in general mosquitoes do not cause trouble by living long.

(f) When the rains abate rapidly the malaria-rate falls less rapidly.

(g) When anti-malarial operations are being carried on, as seen in the second part of Chart 6, the lighter increase of rain in May is responsible for a striking fall of case-rate in June or a month before normal.

(h) The effect of anti-malarial operations has been to cause a general decrease of malaria incidence.

In confirmation of the conclusion that the anti-malarial operations on Ambootia Estate have been effective in reducing malaria, the following facts may be cited:—

Division A in 1921 had no operations and 122 cases: in 1922 slight operations and 133 cases. Whereas

Division B in 1921 had no operations and 56 cases: in 1922 no operations and 112 cases.

Further, Division C in 1921 had no operations and 185 cases: in 1922 most intensive operations and 92 cases.

While Division D in 1921 had no operations and 283 cases: and in 1922 after operations 138 cases.

The most important immediate factor in the situation must be the mosquito fauna and its habitat. That the mosquitoes causing the trouble are stream-breeders was the conclusion come to from the preliminary analysis given above, and those found on the estate were *A. willmori, A. maculatus,* and *A. aitkeni*: the first two, of course, being very dangerous. Other species taken were *lindesaii, barbirostris* and *vagus*, while outside of the estate in stony pools of the bed of the Balasun river *A. willmori* and *A maculatus* were caught in very large numbers.

The Balasun flows in a valley 1,500 feet below the estate about three-quarters of a mile off as the crow flies and whether the valley was not a very great danger or not was a matter for serious consideration. Probably it is not, however, for one section of Division A of the estate with a spleen-index of 0.00 per cent. is situated on a knoll directly above the river, nearer in fact than any other division.

The main object of the observations was to localise the sources of danger on the estate and those made, it is hoped, will enable the Manager, Mr. O'Brien-Webb, to complete the work which has already borne good fruit. To him, as also to Drs. Kingsley-Ward and Winckler the writer owes thanks for the help received and he is also indebted to Lt.-Col. McCombie Young, I.M.S., for his useful criticism of the draft report.

SUMMARY.

An analysis of the malaria-rate with possible contributory factors on Ambootia Tea Estate near Kurseong, Eastern Himalayan foot-hills, leads to the conclusion that the amount of rainfall bears an inverse relation to the malaria-rate at all times of the year. Probably the most important factor in the production of the annual epidemic in the spring months is a rising temperature.

The inverse relationship of the rainfall indicates stream-breeders as pathophors, and *A. maculatus* and *A. willmori* being found everywhere, should be incriminated with causing the trouble.

The inversity of the rainfall to the malaria-rate also provides a means of predicting the severity of the latter. But a better method was found by showing that the severity of the monsoon is inverse to that of the epidemic *in the next year.*

The seepage of subsoil water for months after the monsoon is not a factor of importance in affording habitats for the pathophors, nor is the continued existence of any brood of mosquitoes. A breeding ground of *A. maculatus* and *A. willmori* at a distance of about 1,300 yards and 500 yards vertically below is of no economic importance.*

Anti-malarial operations started at the instigation of Dr. Kingsley-Ward by the Manager, Mr. O'Brien-Webb, have been very successful. They prove that the drainage of swamps and training of streams in which *A. maculatus* and *A. willmori* breed are effective anti-malarial measures, though complete success from their employment is not to be expected. Not only have they reduced the malaria-rate, but this has fallen rapidly a full month before the normal fall would take place. Mr. O'Brien-Webb should be congratulated on his good work.

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PRELIMINARY NOTES ON THE USE OF A SENSITISED ANTI-PLAGUE VACCINE.

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IT is a matter of great regret, though perhaps not surprising, that sensitised vaccines

* Watson in Malaya has found that breeding places of the strong flier *A. umbrosus* at a distance greater than a quarter of a mile are of no economic importance.