FORECASTING EPIDEMICS OF MALARIA.

By R. B. LAL, *M.B.B.S., D.P.H., D.T.M. & H., D.B., Officiating Director, All-India Institute of Hygiene and Public Health, Calcutta.*

(Read at Symposium, August 27-28, 1937.)

The phenomenon of the occurrence of epidemics followed by periods of quiescence as also of the incidence of epidemic exacerbations in endemic areas is not peculiar to malaria. Forecasting of epidemics has exercised the minds of investigators for many years. Some have given it up as something beyond the possibilities of realization; others have attempted it even though they knew that precise results were not likely to be obtained. However, there is no gainsaying the fact that forecasting if successful is of immense value to the practical sanitarian in organizing his resources to meet the situation. It is of equal importance to the epidemiologist who in developing a method of prediction is putting his theoretical principles to a severe test. There are two main principles on which forecasts may be based.

Method 1.—It assumes a more or less complete knowledge of all the factors or at least of the chief factors concerned in the genesis of epidemics and of their interrelationships. Further, it assumes a knowledge of the trend of operation of these factors. If such knowledge were available it would enable one to calculate the result of the interaction of the various processes at any particular time.

Method 2.—It accepts the position that it is not possible to unravel all the causes of the genesis of epidemics, but whatever the force at work may be, one can make use of the recorded experience which when properly manipulated would admit of extrapolation and thus enable one to make a prediction of the future events.

A combination of these methods may also be made use of.

Epidemiology of malaria is a highly complex phenomenon in that here, besides the usual epidemiological factors concerned in the genesis of epidemics, we have to contend with certain special factors, namely the double life-cycle of the parasite and the large number of species of mosquito—a flying insect which acts both as the biological host and the transmitting agent, and in some cases even as reservoir of infection. Ecology of the different species of mosquitoes varies greatly and is subject to modification in certain respects under local conditions. It is therefore not possible to develop any method of forecast which may be of general application.

We are all familiar with the method of forecast which was developed by Gill from his studies on malaria in the Punjab. Malaria forecasts have been regularly prepared according to his method and have been made use of in that

province for over 16 years. No other province has however so far adopted this system. My excuse for presenting this paper is that as one who has been closely associated with Colonel Gill for many years and who has been responsible for drawing up annual malaria forecasts for a number of years, I think it is an ideal opportunity for inviting a discussion on the subject. Gill's method of forecast is based mainly on the first of the two methods enumerated above, although to a certain extent use has also been made of the second principle.

Gill's main thesis is that the occurrence of epidemics is the necessary sequence of the upsetting of balance between the quantum of infection and the quantum of immunity of the herd in favour of the former.

The principal factors concerned in the quantum theory of infection are :—

(1) The number and distribution of gametocyte carriers as also the intensity of their infection, in other words the size of the reservoir of infection.

(2) The degree of herd resistance.

(3) The number, distribution and habits of the malaria-carrying mosquitoes.

(4) Accessory factors influencing—

(*a*) the resistance of the community,

(*b*) the breeding places and the extent of the life of the chief malaria-carrying species,

(*c*) the development of the sexual cycle of the parasite in the insect, and

(*d*) the exposure of human beings to the bite of mosquitoes.

Each of these items, I need hardly say, presents a chain of problems about many of which our knowledge is rather scanty. Some of these problems will in fact form the subject-matter of discussion during this symposium and we hope to receive some further light on them. However, the point I want to make is this that besides the fundamental lack of exact knowledge, we have very limited means of collecting the necessary data in actual practice. Moreover, the geographical units for which even these scanty data may be available are too large and perhaps too heterogeneous to admit of detailed study. We cannot, therefore, be too critical about the results that may be achieved from such investigations. We must, however, remember that mathematical studies by Ross and his co-workers by the method of *a priori pathometry* have shown that big upsets in the finely adjusted host parasite balance may be caused by relatively small quantitative changes in the causal factors. Bearing these points in mind we could proceed with a brief discussion of the factors actually made use of in Gill's method of forecast.

1. *The spleen rate of school children taken all over the province in the month of June.*—For purposes of forecast this is intended to provide an index of malaria experience of the community in the previous year and is made use of as a measure of immunity status of the population. It may on the other

hand under certain conditions be interpreted as a measure of the rate of recovery, a high spleen rate indicating low resistance and *vice versa*. Again it may also serve as an estimate of reservoir of infection. The interpretation of the spleen rate in the absence of other relevant information is, therefore, by no means simple.

2. *Rainfall.*—Weekly rainfall figures are collected from a large number of recording stations which, though not evenly distributed throughout the province, give fairly good information about the comparative strength of the monsoon in various parts of the province when compared with the normal. These figures are intended to serve as a guide for the estimation of the breeding places of the mosquitoes in different parts of the province. However, for proper interpretation of the rainfall figures a knowledge of the lie of the land is necessary, because there are considerable differences in the efficiency of drainage in different areas and besides there are important differences in the nature of the soil from place to place. A rough index of the significance of rainfall in relation to the incidence of malaria in different districts is provided, as we shall see later by the coefficient of correlation between rainfall and fever mortality.

3. *Economic condition.*—The statements supplied by the Director of Land Records afford an idea of the prevailing economic conditions in different parts of the province. These estimations are taken into consideration in formulating the forecast.

4. *Epidemic figure for each thana or town.*—This is the index of incidence of epidemic malaria suggested by Christophers. It is calculated by dividing the fever mortality for October by the average fever mortality for the months of April, May, June and July of the same year. This serves as an index of the incidence of malaria in the locality during the previous year. The centres showing high epidemic figures are not expected to suffer from epidemic malaria in coming years.

5. *The epidemic potential factor.*—This is the coefficient of variation of malaria deaths which serves as an index of the possibilities of the occurrence of epidemic malaria in the district—a district with a high figure is, other things being equal, more liable to suffer from epidemic malaria than one with a low epidemic potential factor. This figure is low in areas like Kangra district, where malaria is endemic.

6. *The coefficient of correlation between rainfall and fever deaths for the month of October for the districts.*—These figures are intended to help in interpreting the rainfall figure. In Kangra district the coefficient is negative and high, but in most districts it is positive but varies in value.

In regard to the last three factors it will be seen that the underlying assumption is that the fever mortality figure for October (sometimes the November or even the December figure is taken in place of the October figure if it is high) is a measure of deaths due to malaria. This assumption, I think, is not based on sufficiently convincing evidence. At any rate, the relation of these figures

to the number of attacks is very uncertain. Moreover, for calculating the last two factors areas too big have been taken, which from local knowledge one can say are far from homogeneous with respect to those factors.

Besides these factors information about the localities affected by floods is taken into consideration. The distribution of total rainfall during the two months is also taken into account. If most of the rainfall has been concentrated in a week or so and especially if it has been mainly confined to the earlier period, it is not considered significant even though excess above normal may be fairly high.

Through the courtesy of Dr. M. Yacob, Epidemiologist to the Punjab Government, I have received some of the data for the different districts of the Punjab which were used in the preparation of malaria forecast last year. A preliminary forecast is issued on the basis of information available by the end of the fourth week of August and the final and more detailed forecast is issued on the 15th September on the basis of full information available up to the end of August. Dr. Yacob's preliminary forecast for 1936 reads as follows :—

'*28th August, 1936.*'

'A study of the forecasting factors including the available rainfall data up to August 24th does not point to the occurrence of a severe or widespread epidemic of malaria in the Punjab during the ensuing autumn.'

'Localities in which epidemic malaria is mainly expected to occur are the tracts inundated by flood water from the Ravi and Beas rivers and the Bhimbar and Sakki nullahs, namely parts of Sheikhupura, Gurdaspur, Lahore (including the environs of Lahore town), Amritsar and Gujrat districts.'

'Localized epidemic foci of mild intensity are likely to develop in Rohtak district (Sampla and Jhajjar); Gurgaon district (Ferozepur Jhirka, Gurgaon and Ballabgarh); Ambala district (Ambala); Ludhiana district (Samrala); Lahore district (Kasur) and Sialkot district (Daska).'

'The final forecast based on analysis of complete rainfall data up to 31st August will be issued on September 15th, 1936.'

His final forecast was issued in the following terms :—

'*15th September, 1936.*'

'As a result of a study of rainfall data up to August 31st, 1936, and of other factors concerned in the causation of epidemic malaria the following deductions are drawn :—

1. No major epidemic of malaria is likely to affect the province as a whole during the coming autumn.
2. Epidemic conditions are, however, likely to prevail in parts of Lahore (environs of Lahore town and Kasur); Amritsar, Sheikhupura, Gurdaspur (Batala and Shakargarh), and Gujrat districts.
3. Localized epidemic foci of mild intensity are likely to develop in Rohtak district (Jhajjar and Sampla); Gurgaon district

(Ferozepur Jhirka, Gurgaon and Ballabgarh); Ambala district (Ambala, Kharar and Rupar); Hoshiarpur district (Una, Garhshankar and Hoshiarpur); Jullundur district (Nawanshahar); Ludhiana district (Samrala); Ferozepur district (Zira); Sialkot district (Daska); and Rawalpindi district (Rawalpindi).

4. Throughout other parts of the province, except in tracts flooded by rivers and storm water channels, autumnal malaria incidence is not expected to attain abnormal magnitude.'

The previous year's forecast is checked up every year after the epidemic figures have been calculated.

The annual forecast as issued by the Epidemiologist is of considerable assistance to the health officers. Perhaps it is possible to further improve the method at present used, but the point I specially wish to emphasize is that personal experience of the conditions obtaining in the province not displayed by these data is an important factor in the preparation of a good forecast.