THE PRINCIPLES OF THE PROPHYLAXIS OF MALARIA: WITH THE ADMINISTRATIVE AND OTHER MEASURES FOR THEIR APPLICATION ON ACTIVE SERVICE.

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DESTRUCTION OF MOSQUITO LARVÆ AND PUPÆ.

Next to be considered is the method which aims at the destruction of the developmental stage of the mosquito, a measure which has been conspicuous by its complete and brilliant success in some places and by its almost equally complete failure in others.

An example of success is to be found in the campaign which was conducted in Ismailia, a small town on one of the lakes through which the Suez Canal runs. This town was originally intended by De Lesseps to be the headquarters of the Suez Canal Company, and a port of no small magnitude. In order to bring to it an adequate supply of fresh water a canal from the Nile was constructed and opened in 1877. The supply of water from this was abundant, but unfortunately its drainage was not effectively controlled, so that marshes and pools of stagnant water sprang into existence, mosquitoes bred in swarms, and malaria became rampant. From that date until 1902 the disease flourished apace, providing as many as 2,500 cases in one year, and in inverse proportion the prosperity of the town waned, and it came to be regarded as a plague spot to be avoided at all costs.

In 1902 Ross was asked to advise the authorities, and mapped out a campaign based on the drainage of marshes, the filling up of pools, the canalization of streams to produce running water, and the treating of unremovable collections of water, such as cesspools, with kerosene. This proved so effective that in 1906 there were no fresh cases of malaria, and since that date the town has been relatively free from the disease.

In striking contrast is the state of affairs which obtained in Salonica from 1916-19. The possibility of the occurrence of an epidemic of malaria was foreseen, and in 1916, limited prophylactic measures were undertaken. In 1917 and 1918 vigorous and very extensive anti-mosquito measures were in full swing, but with such little effect that Wenyon, who was in charge of the Malaria Research Laboratory in Salonica, states that "in most places little or no good was done by attempted mosquito destruction" [18]. Statistics of the cases which occurred and the personal experience of all who studied the matter bear out the truth of this statement.

1 "Parkes Memorial Prize Essay."
To reconcile these diverse results, neither of which is unique, the methods adopted must be taken into consideration. The theory of mosquito larva destruction is one of alluring simplicity. The impregnated female mosquito lays her eggs on the surface of water, and according to her species selects her particular kind of water, some preferring marshes and little stagnant pools of water, some wells, and some streams. Here in two or three days the eggs hatch into larvae, which swim about feeding greedily, but which though they pass their lives in water must draw the oxygen they require from the air. In due course (from a few days to several months, according to the season of the year) the larvae develop into pupae, which are also aquatic and breathe in the same way, and these after undergoing further development give rise to the mature insect. The aquatic stage in the life history is the most suitable for the destruction en masse, for if water in a form suitable for the breeding of the mosquito can be abolished no multiplication can take place and the insects will die out. Alternatively where this is not altogether practicable there is yet another line of attack in treating the water with chemicals. Thus if oil is spread on the surface of water the larvae are unable to breathe through the film which forms and so are rapidly suffocated; or again, certain chemicals may be added to the water to kill the larvae.

Unfortunately the simplicity of the theory is too often outshone by the complications encountered in its practice. The problem bristles with difficulties which may be so great as to throw the matter out of court on the ground of impracticability.

In the first place all anopheline mosquitoes are not carriers of the malaria parasite, and in the second place gross variations with regard to breeding habits are found among the different species of anophelines. Thus it often happens that in a mosquito-infested district where malaria is occurring, only a small proportion of the total mosquitoes are of the carrier type, and these may have quite specialized breeding habits, so that general measures of mosquito destruction might miss them altogether. The first essential in any district is therefore to make a critical survey to ascertain what mosquitoes are carrying the parasite and what their breeding habits are; after which, if feasible, steps specifically directed against the carrier species may be undertaken. The marking down of the carriers and their habits is no easy task, and could not well be done efficiently in less than a year [19]. If it is not desired to postpone steps for this length of time, by catching and identifying large numbers of mosquitoes, and consulting the literature, valuable information can be obtained as to the best measures to adopt against those known to be carriers.

To illustrate the diversity of breeding habits the following instances may be quoted:—

Anopheles maculipennis, a well-known carrier, breeds chiefly in swamps and marshes, and does not breed in running water, so that it can be attacked by draining the swamps. Conversely, A. maculatus, which gave rise to
much trouble in the Federated Malay States [20], breeds in running water. Other things being equal, therefore, draining by open drains (the usual method) would not abolish but rather encourage the breeding of this species. Yet another, *A. stephensi*, is almost exclusively a well-breeder and can only be countered by screening or oiling the responsible wells. It can thus be seen that haphazard measures are almost bound to involve a waste of time and money, and may even render the last state of affairs worse than the first by taking away conditions under which harmless mosquitoes were breeding and replacing them by others suitable to the propagation of carrier species.

The following measures embrace all the different types of anti-larval work, but only those which affect the proven carrier should be adopted in any district.

Drainage is adopted in the case of marshes and swamps and areas where “seepage water” appears, the latter usually occurring where a permeable layer of soil outcrops on a hillside. It is much better that the work of drainage, if it is of any extent, should be carried out by competent engineers, to whom it should be explained that dryness of the soil is the object in view. Experience has shown that for marshy tracts of lands open drains, if possible lined with concrete; with sloping sides, and rounded towards the bottom, are most efficient, and are to be preferred to underground drainage by unglazed pipes [21]. A special type of open drain, lined by concrete reinforced with wire netting, was found to be most successful in Panama. Simple ditches or drains cut in the earth, while they may be made to serve, have the grave disadvantage of needing constant attention on account of their getting choked by vegetation or broken down by cattle. Whatever type of drain is used it must tap the whole of the marshy area, and in the case of concrete drains have “weep-holes” at frequent intervals. The system should consist of numerous branches joining up into one main channel in which the water is led away to a convenient watercourse. The result of such a system of drains, well executed, is to lower the level of the subsoil water and convert the swamp into dry land. The gradient of the drains is important—there should be a regular fall sufficient to ensure a steady flow of water.

Seepage-water is most successfully treated by a series of drains across the face of the hillside, connecting with another running to the bottom of the hill and opening into the nearest watercourse. Underground tile-drains have been found most suited to this particular purpose.

Streams and ditches are treated by canalization, that is, by constructing central channels of definite gradient and sufficiently large in section to take all the water, so that there is a constant flow and all pools and backwaters are eliminated. The work of canalizing a stream may be very considerable, involving blasting in some cases. It is furthermore a constantly recurring task, as in addition to the depredations of men and animals, showers of rain causing torrents are apt to wash away the work which has been done.
This is not a measure to adopt in the presence of carriers which breed in running water.

Small ponds may be dealt with by draining or filling in, but often this is impracticable, and generally it is so with large ponds and lakes. In these, mosquito breeding occurs round the edges, among rushes and rank grass. The edges should therefore be freed from vegetation by cutting or burning, both to allow the natural enemies of the larvae to have access to them, and to permit of easy application of larvicide as will be described.

Casual collections of water in connexion with dwellings and gardens need constant attention. It is a safe rule to empty and dry at least once a week all vessels, mini-ponds, etc., containing water, for as the aquatic stage of a mosquito's life occupies longer than this period, no eggs laid can come to maturity; but care must be taken that the larvae or pupa poured out are actually destroyed and do not find their way back again. Old jam tins should be flattened out. The possibility of water lodging in a sagging roof gutter must not be forgotten; this applies equally to cavities in trees, hollow bamboos, and other similar potential breeding places. The remedy in each case is obvious.

Unavoidable collections of water for domestic purposes such as wells or storage tanks where there is no piped supply should be protected from ovipositing. They may either be covered in completely by wood or galvanized iron, or may be screened by means of wire gauze (screencloth). The mesh of the latter is of importance. When made of 30 I.S.W.G. wire, a mesh containing fourteen holes to the linear inch will prevent the access of mosquitoes, but where there is the possibility of eggs being washed into the tank, an 18-hole mesh screen cloth should be used. The newly emerged imago is soft and might find egress through the coarser mesh, but would be stopped by the finer [22].

It should also be emphasized that piped water supplies will prove a source of trouble unless steps are taken to drain away the waste water. Similarly, engineering operations which involve the damming or diverting of streams may bring about mosquito breeding. An intelligent anticipation of such contingencies will often make it possible to avoid the dangers involved.

Lastly, in combination with many of these measures it will be found advisable to use larvicides. Oil is most commonly used because of its safety. Crude oil has been found most satisfactory, though it has the disadvantage of being difficult to spread into a good film. Kerosene spreads better, but the film is more easily broken by wind, and it is expensive. Oil acts better when sprayed on the surface of water. This, however, may involve considerable labour, and has led in some cases to the employment of automatic oiling devices. Of these the most commonly used is the "dripper," which allows so many drops per minute to fall on the water which is being treated. Unfortunately owing to the viscosity of the oil such drippers are very liable to go out of order, and cannot be left for long
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without attention. They are suitable for ditches and slow flowing streams where a constant application of oil is required. Where continuous oiling is not applicable, as along the edges of lakes, or elsewhere where water cannot be removed, periodic applications must be made at intervals to be decided by a study of the mosquitoes which are being attacked, the interval being less than the time which it takes an egg to develop to a mature insect. Once a week is a rule that will cover most cases. Prior to oiling, all obstructions likely to break or interfere with the film should be cleared away. Such oiling was extensively used in Panama for lakes and other collections of water which could not be drained, as well as for ditches and small streams.

Poisons which mix with the water and destroy the larva\textae\ in this way by direct action must be non-toxic to domestic animals and man. This is a difficult condition to fulfil, and one which militates against the use of such preparations, for short of toxicity larvicides render water unpalatable, and in densely populated countries such as India there are few sources of water which are not used for drinking purposes. This is in fact a condition which constitutes a never ending obstruction to all anti-larval measures. The nullah which is responsible for mosquito breeding is generally the washing ghat of the bazaar, and canalization is an almost impossible ideal. It has inevitably the opposition of the native, who cannot be expected to understand the necessity for it, and if he does probably looks on it as a greater evil than the mosquito.

In Macedonia, cresol was used as a larvicide with some success [23]. It was found that a concentration of 1 in 100,000 prevented mosquito breeding, yet was harmless to animals and vegetation. In Panama preference was ultimately given to a soap composed of resin, soda, and carbolic acid.

The use of the natural enemies of mosquitoes has at present only a very limited application. Larva-eating fish may be introduced into ornamental fountains and ponds, but it is exceptional for the larva\textae\ not to be able to find some hiding place where they can remain unmolested. More drastic measures are generally necessary.

In brief review of all these measures, it will be seen that the crux of the whole matter is the practicability of any scheme of larva destruction when considered in terms of pounds, shillings and pence. There is little doubt, that given the necessary capital, and access to the necessary labour, one could render any area mosquito free, but before embarking on such a scheme it is well to consider the "pros and cons." In this the experiences of the past, both successes and failures, are the best guides, but the difficulty often arises that other methods besides larva destruction have been employed and it is not always easy to determine how far results are due to larva destruction and how far to other things.

It is readily obvious that Ismailia is a very nearly ideal spot for such measures to succeed. It is but a small and circumscribed oasis in an arid
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The breeding places can all be accurately assessed and periodically treated. Supervision is easy. Immigrant mosquitoes present no real menace. The indigenous mosquitoes which carry the disease are of the domestic type, specialized in their habits and breeding places and hence easily routed. Owing to the relative density of the population, measures can be conducted at a low expenditure per head. The population is largely under the control of the Suez Canal Company and hence amenable to discipline. Everything augurs well, and it is little wonder that the steps taken have given good results.

Similar good results were obtained at Port Said, where conditions were comparable except for a greater degree of official obstruction. Of Cairo, the same cannot be said, because it was impossible to make the campaign universal. Nevertheless a reduction was affected in certain areas.

In the city of Athens it was found that the bed of the river Ilissos was responsible for large numbers of mosquitoes. This was canalized, and a remarkable fall in the number of cases of malaria ensued. Here no other measures were employed [24].

In parts of Mauritius, and in certain districts in India, the amount of malaria has become negligible through the application of anti-larval measures.

In the famous Panama Canal campaign, it is difficult to estimate what proportion of the excellent results obtained was contributed by the different measures adopted, for every known method was put into operation (at an expense, it may be noted, of 350,000 dollars per annum, the total area involved being about fifty square miles) [46]. Thus, screening of quarters was compulsory, and “quinine dispensers” spent their whole time going from gang to gang giving the negroes quinine. Le Prince fully details the measures adopted, but unfortunately gives no statistics showing that a reduction in mosquitoes actually did occur. Coupling with this the statements that from 1911 onwards (the campaign having started in 1904) mosquito traps were used and “it was not uncommon to catch several hundred per night in one trap” [26], that “in the screened barracks of Miraflores in April, 1912 (the dry season), the average daily catch was sixty, but that as many as 500 had been caught in one barracks at other seasons” [27], that at Gatun, between January and March, 1913, more mosquitoes were found than had been found in any settlement since work began on the canal [28], a considerable doubt arises as to whether the actual larva destruction played the leading part that is often attributed to it.

In Italy, where malaria has been very prevalent and much study in prophylaxis has been undertaken, it is recognized that, in rural districts at least, complete destruction of mosquitoes is a very problematical accomplishment, and more is attempted by means other than drainage.

In the German colonies in pre-war days Koch and others came to the conclusion that prophylaxis by mosquito reduction was impracticable.

During the war measures on a large scale were tried on several fronts,
and their results are very instructive. The case of Macedonia has already been cited. Here there existed a state of affairs which presented an almost complete contrast to that in Ismailia. Units of the army were scattered over a tract of country containing lakes and marshes many square miles in area. The uplands and hills were furrowed by a maze of small streams in which Anopheles superpictus, an active carrier of malaria, bred freely. The whole country was a potential breeding ground, and in actual fact proved to be mosquito infested. In the base areas, where the troops were more or less densely packed, it was possible to treat all the breeding places thoroughly and a reduction of mosquitoes was brought about, but up country, where it was beyond the power of units to attend to breeding places outside a half-mile radius from their camps (and in many cases not so far as this) large tracts of country were of necessity left untouched or placed under the care of “anti-malarial squads” who inevitably had more work than they were capable of executing properly. It is little cause for wonder that the reduction of mosquitoes was barely appreciable when the immensity of the task is taken into consideration; for the work of drainage and canalization is a veritable task of Sisyphus. Any reduction which did occur was to little purpose, for as Wenyon points out [29], “when the number of mosquitoes attacking an individual amounts to hundreds if not thousands, the reduction of these by a small proportion will hardly lessen the man’s chance of infection.” Always there was the immigration of mosquitoes from areas where for the moment breeding was unchecked, and more especially was this the case near the front line where the proximity of the enemy led to large areas going untouched. Finally the expense, especially in man power, of these attempts at mosquito destruction was very great. Each unit had to contribute labour, which means that soldiers were diverted from their proper duties, and in addition large gangs of natives were employed, all, as can be seen now, with little effect.

In Palestine, during the stationary phases of the campaign, a good measure of control was obtained, the circumstances being comparatively favourable, but as soon as the final advance took place the control broke down and the disease became rampant.

**Conclusions regarding Anti-Larval Methods.**

There is only one conclusion to be drawn from all these experiences, namely, that every case must be judged on its own merits. In small and urban areas such as Ismailia, where success can be more or less assured, larva destruction is par excellence the method of malaria prophylaxis. Conversely in countries such as Macedonia—sparsely populated, marshy, ubiquitously prolific of mosquitoes—it is unlikely that much good will be done other than by drastic and impossibly expensive drainage. In any case before undertaking such measures, the situation should be assessed as accurately as possible, and an estimate made of the degree of the reduction of the carriers which might be expected, in the light of past experience, to
result from the measures proposed, and unless it is anticipated that the reduction will be very nearly absolute, it would be well to consider whether "the game is worth the candle," and the energy and money had not better be expended in other directions.

As far as active service is concerned larva destruction can have but a limited application. Its rôle is that of a permanent rather than of a temporary measure. In a country which can justly be called malarious its efficient execution involves an expenditure of capital which could rarely be justified except on the ground of results to be reaped for years to come; to employ it in a half-hearted fashion is to court disaster. It is apt to be slow in producing results. It involves much labour, and at best is bound to be limited, often at the most important points, by enemy action. For all these reasons it cannot be considered to rank high among war-time measures. In base areas it may be possible to inaugurate suitable schemes, but elsewhere, beyond dealing with flagrant breeding places, actually in or in immediate proximity to camps for the sake of sanitary discipline and a partial increase of comfort, it is doubtful if such measures will ever be of real practical value.

PROTECTION FROM THE BITE OF THE MOSQUITO.

In the protection of the individual from the bite of the mosquito lies the third main line of defence. This method, when effective, acts in two ways; it prevents mosquitoes from becoming infected by sucking blood containing gametocytes, and it prevents those already infected from passing on the parasite to man. Methods of destroying adult mosquitoes (as distinguished from anti-larval measures) are included in this section.

First of all a measure of protection can be afforded to any camp or village in which mosquitoes are not actually breeding, by cutting down and clearing surrounding brushwood and jungle, and by doing away with anything in the form of undergrowth or other shelter which might afford protection to mosquitoes. The insects take refuge in the shady depths of such vegetation during the day, and do not tend to frequent places which fail to afford such shelter. During the construction of the Panama Canal it was a standing order that brushwood be cleared for 200 yards round every village and camp, and Gorgas considered this a measure as important as drainage [30]. The observations made by Le Prince [31] on the "flighting" of mosquitoes run somewhat contrary to this idea. Le Prince at Gatun, in 1913, observed and demonstrated to others that at dusk mosquitoes, which were breeding freely in a marsh over half a mile from Gatun, flew in clouds to the village, passed the night there, and flew back at dawn to the marsh. A migration of sorts had been previously recorded, and is noted by Ross [32], but this author, although aware of its possibility, appears never to have encountered personally such a phenomenon, and it is probable that it arises only in certain circumstances, and does not really invalidate the principle of clearing undergrowth, the more so as in
practice measures of this kind have undoubtedly proved effective in reducing the numbers of mosquitoes in a locality.

Either by itself, or in conjunction with scrub clearing, some method of destroying adult mosquitoes which remain in or about dwelling houses and tents or dug-outs during the day-time is of great value. This is especially important where there is any possibility of the insects having obtained access to an infected person. As a rule, a mosquito which has just had a heavy meal of blood is lethargic and does not fly far, and thus those found about dwellings in the day-time are the ones whose destruction is most important.

Mosquito traps may be used for this purpose. A good mosquito trap is so constructed and placed that it offers seductive shelter for the day-hours to insects that have visited a dwelling during the night. There are many types of trap. A fairly deep box lined with dark blanket and with a lid or door so that it can be closed readily will be found quite effective. As daylight advances the mosquitoes fly inside to the dark and cool corners and settle there to pass the day. When morning has advanced so that there are no more in flight, the door is closed, and a little chloroform or ether introduced to kill those caught. Another form of trap is a rectangular framework covered by mosquito netting, and having a door at one end [33]. This is placed in a convenient spot with the door slightly ajar, and is rendered dark by throwing over it a tarpaulin or some similar covering. To add to the catch other possible resting places should be kept disturbed. In due course the door of the trap is shut, the tarpaulin removed, and the insects may either be killed by placing the trap in strong sunlight for a few hours or may be kept to be destroyed at will. In such a trap suitably placed in a garden in Colombo, James caught an average of 280 mosquitoes per day over a period of two months. Such catches must have a considerable effect in reducing the numbers of infected mosquitoes.

Another method which became very popular in the latter part of the Panama campaign was "hand-catching," a man being trained to go round barracks each morning and to catch all the mosquitoes therein either with a test-tube or with a hand-net, or alternatively to kill them with a "swatter." This leaves less to chance than the trap, and requires a minimum of apparatus, but is difficult to apply to barracks or bungalows with lofty roofs where the mosquitoes fly out of reach. This difficulty has, however, been overcome with some success by whitewashing all walls and roofs and painting a black band round the wall at an accessible height [34]. The mosquitoes select the black band as a resting place in preference to the white, and can be destroyed there. Striking instances of the reduction of malaria attributable to hand-catching of mosquitoes are quoted by Le Prince [35]. The method is a very effective one not because it does much towards reducing the actual number of mosquitoes, but because it deals largely with those particular insects which in due course may become infected. It is furthermore simple and capable both of application under all circumstances and of easy supervision.
Occasionally a bungalow or a barrack room becomes so infested by mosquitoes that special steps in the shape of some form of fumigation have to be adopted to get rid of them. The burning of sulphur in quantities of two pounds per 1,000 cubic feet is effective, care of course being taken to seal the apartment which is being treated. The fumes are allowed to act for two hours. Unfortunately sulphur has a deleterious effect on metals and fine fabrics. Pyrethrum powder is substituted on this account. It is used in the same quantities, but has to act for four hours and may only stun mosquitoes, so that after using it they must be swept up and burned.

Whilst it is an undoubted fact that anophelines will bite during the day in shady places, nevertheless from dusk to dawn is the usual time of attack, and it is during this period that protection is required.

Ideal protection is afforded by screened bungalows or huts. These may be constructed in a variety of ways, but must all have doors, windows, and ventilators protected by screen-cloth of a sufficiently small mesh (fourteen strands to the linear inch of 30 L.S.W.G. wire) to prevent the ingress of mosquitoes. In bungalows it is usual to screen off verandas, as these are used both as dining and as bedrooms. Doors where possible should face the prevailing wind as mosquitoes tend to collect to leeward and are more liable to make their way through doors on that side. Some automatic closing device should be incorporated in all doors. Unfortunately screening of this type has little scope under active service conditions, as it is but rarely that it is practicable.

From dusk till bed-time where there is no effective screening, no parts of the body should be left unnecessarily exposed. Men should have "turn-down" shorts to cover their knees. Officers and nursing sisters should have their ankles thoroughly protected by thick hose or preferably by "mosquito boots." Hands and faces should be carefully watched, in which connexion a little mutual co-operation is of great value. In the case of sentries and picquets or nursing sisters on night duty, gloves and face-nets may be used, the "Simpsonette" being a useful model of the latter. The drawback to all such devices is that they are apt to be insufferably hot and are often surreptitiously discarded for this reason, also to a certain extent because they interfere with the performance of duty. Though their use should be encouraged, too much reliance cannot be placed on the protection they will afford.

An alternative is the use of repellants—chemical substances distasteful to mosquitoes which are applied to exposed parts in the hope that they prevent the insects from biting. Essential oils of various kinds are used for this purpose, the best known being citronella oil or oil of lemon-grass. In India a mixture of oils known as "bamber oil" is now used as a routine measure. It contains citronella oil, coconut oil, kerosene, and carbolic acid [36]. The objection to all repellants is that they evaporate off or are absorbed and so lose their effect. This makes them of dubious
value for protection during sleep, but in the case of people doing night duty repeated applications can be made and a very useful purpose served.

Electric fans, where they are available are of considerable service in keeping mosquitoes away from their victims, but their use is very limited. Hand fans as a measure for keeping off mosquitoes are by no means to be despised. A palm leaf fan and a small hand net were favourite weapons by the use of which Ross added to the comfort of his evenings.

The last and by far the most important of all measures of protection is the bed net or mosquito curtain. Although a person is liable to be bitten during the evening hours, the fact that he is alert and moving about makes him less accessible to the insect, and it is a matter of common experience that the majority of bites are acquired during the hours of sleep. All such bites can be avoided by the intelligent use of a suitable bed-net, and the chances of malaria infection can thus be enormously reduced.

What are the essential features of a good bed-net? As regards fabrics it must combine several characters. It must have a mesh sufficiently small to prevent the passage of the mosquito; it must let through as much air as possible, and it must be sufficiently strong to stand wear and tear. The factors concerned in this are therefore the thickness of the cotton used and the closeness of the mesh. The correct trade method of estimating the mesh of netting is rather peculiar, and consists in counting the number of holes along a line of the warp and a line of the bobbin falling within a superimposed square inch, and adding these two counts together. If this should be, say twenty-five, the netting is said to contain twenty-five holes to the square inch, though of course the actual number of holes is much greater than this [37]. MacArthur has shown that netting woven of 30/8 or 40/60 cotton with twenty-five or twenty-six holes to the square inch (trade counting method) cannot be passed by Stegomyia fasciata. That made of 30/8 cotton owing to its greater strength is probably the better of the two for active service use.

For ordinary beds a rectangular shape of net is better than a bell shape, as the user's arms are less liable to come in contact with the side. The net should be both long and broad to obviate as far as possible the sleeper throwing bare arms and legs against it; in any case the net should have a strip of calico sewn round it above the level of the mattress to prevent exposed parts from being bitten through the meshes. The net should be hung so as to allow as much space as possible above the sleeper for the sake of coolness, yet should be long enough to allow of liberal "tucking in" under the mattress... It should be tightly stretched to allow air to blow through. Where such precautions are observed there is little fear of the occupant being bitten whilst asleep.

The use of the mosquito curtain is applicable either in peace time or on active service. For the latter a special form of net needs to be provided and arrangements for its transport made, but so great is its importance in reducing sick rates that these are minor difficulties which must be overcome
by one means or another, In Salonica a satisfactory net was ultimately evolved. This was bivouac-shaped and was made to hang under bivouac waterproof sheets. Each net was devised to take two men, who entered at one end. This end was weighted by filling pouches round the bottom of it with sand. It ran on rings along the front guy rope, and so automatically fell to the ground in good position when the occupants entered and released it. To perfect such a bivouac it is necessary to dig a central trench eighteen inches deep, and on either side two bed platforms six inches below ground level.

It is important that nets should always be available, that they should be kept in good repair, and that a sufficient number of spare nets should be easily accessible to afford immediate replacement of any net seriously damaged. Even in the absence of bivouacs it requires very little ingenuity to hang a net by some improvised means, and nothing should ever be allowed to serve as an excuse for not using the net. The interest of officers in this matter should be directly stimulated. Frequent inspections should be made, and strict supervision of the use of the nets exercised.

Provision of one kind or another should always be made for people travelling by train at night, which in India is a very fruitful source of malaria. Nets are rarely practicable, but repellants can always be used and should be made a routine measure in these circumstances.

**Prophylactic Quinine.**

In the use of prophylactic quinine we have the fourth line of resistance, one which aims, by the exhibition of small doses of quinine, at destroying malaria parasites as soon as, or very shortly after, they have been introduced by the mosquito. In the broadest sense of the term it also includes quinine given with a view to preventing relapses in a malarial patient, but as this has already been discussed when considering the elimination of the reservoir of infection, no more need be said than that there is no question as to the value of quinine given for this purpose. It to a large extent prevents relapses, and where it does not completely do this it at least greatly reduces their number, and also the number of gametocytes in the peripheral circulation, a point of no small importance in relation to the infection of mosquitoes.

The methods of administering prophylactic quinine are numerous, but they can roughly be divided into those in which the drug is given regularly each day, and those in which larger doses are given at intervals of a few days. Perhaps the most approved method is to give five grains each evening an hour before dusk. James recommends a further five grains about midnight to be taken where a mosquito curtain is not being used, the reason for the second dose being that, as quinine is fairly rapidly eliminated from the circulation, this method is more likely to ensure the presence of a proportion of the drug in the blood during the night. Koch's method [38] was to give fifteen grains on the tenth and eleventh days. The argument
against this second method is that should an individual be bitten as soon as the effect of the dose has worn off, the parasite has eight or nine days in which to multiply before it is subjected to the action of a further dose, and is consequently not so amenable to the drug. In a very malarious country this method is therefore unsuitable, and the consensus of opinion is that in general the daily dose is best. In the quantities given its unpleasant effects are practically nil, and when taken regularly each day it is less apt to be forgotten than when it falls due at intervals.

Much controversy has raged round the question as to whether prophylactic quinine, however taken, has any value in preventing malaria. It was certainly used on a large scale in several theatres during the late war without any very apparent good results ensuing. Thus Wenyon [39] in reference to Salonica states that in his opinion the expenditure of money and labour involved in the administration of prophylactic quinine was not worth while. The French in Macedonia had equally disappointing results, as according to Paisseau [40], although the mortality was probably reduced by this means, there was little evidence that the incidence was similarly affected. Treadgold [41], in an investigation of a rather small number of cases, reaches the conclusion that in Macedonia quinine alone is quite unable to prevent malaria. Watson [42] writing with reference to the Federated Malay States, concludes that the use of quinine can never make any material reduction in the liability to infection in an intensely malarious locality.

On the other hand, however, there are a host of opinions in favour of the use of prophylactic quinine. Treadgold [41] has analysed 201 original papers, and finds that 134 of the writers favour this method, 27 favour it with reservations, and 40 are against it. Those who advocate its use include such experienced observers as Ross, James, Celli, Koch and the brothers Sergent, to quote but a few.

How can such divergent opinions, based on results, be reconciled? Wenyon suggests that the explanation lies in the existence of certain strains of plasmodia which are quinine resistant, and are not affected therefore by the prophylactic dosage. Among trypanosomes the existence of analogous drug-resistant forms has been definitely proved. In a country where mosquitoes are relatively few such resistant strains of parasites run a much smaller chance of being transmitted than they do in a country where mosquitoes are very numerous, where an individual may be bitten several times per night by infected mosquitoes. Such a person has a much greater chance of being infected with a resistant strain, and through the selective action of the quinine this resistant strain is prone to increase. This author admits that this is a purely speculative theory, yet it fits in well with facts. Gosse [43] in describing a small but well controlled investigation in Mesopotamia, where the results were good, suggests that good results and bad results depend on the intensity of the infection, quinine in the doses usually given being of less value where a large number
of infected oites per day are received. Ross implies a similar explanation in a footnote on Watson’s contribution to his book [44].

Another possible explanation of diverse results lies in variations in the thoroughness with which the quinine administration is carried out. In certain jail experiments in India [45] very good results were obtained where the administration was rigidly controlled. On active service, given the best will in the world, absolute regularity for everyone is a very difficult ideal to attain, and the failures may in part at least be accounted for through lack of continuity in administration. Whatever the cause it remains a fact that the results of this method under active service conditions in intensely malarious countries have not been good.

To summarize, it would seem that where mosquitoes are not unduly numerous, and where administration can be rigidly controlled, prophylactic quinine is of value in preventing malaria. It appears to reduce the severity of such cases as do occur. Conversely, in an intensely malarious country where mosquitoes are very numerous, and especially under active service conditions, its value is much more doubtful.

**Administrative and Other Details with Reference to Active Service.**

These, then, are the four methods by which malaria is attacked. All will be seen to have their limitations, some having a much more specialized application than others. It must again be reiterated, that although theoretically a combination of all methods should give the best results, in actual practice it has been proved best to select, concentrate on, and bring as near perfection as possible, one method. Especially is this the case on active service where a cut-and-dry, universally and rigidly applied scheme is sure to give better results than a diversity of half-hearted measures.

It remains now to crystallize out from all these principles a scheme which will embody the most suitable measures for active service. In doing so the governing factor to be borne in mind is that the function of an army is to conquer the enemy, and that the preservation of the health of the army is a means to an end and not an end in itself. This must therefore be accomplished by the most economical means compatible with good results, and with as little derangement of the normal duties of the soldier as possible. By this it is not meant that sanitation should be looked on as a secondary matter, but that sanitarian and combatant must adjust their perspective to the facts of the case, and by mutual co-operation reach the highest mark of efficiency.

**Matters to be Considered Prior to the Inception of the Campaign.**

Questions of the time of year in which a campaign (if a short one) is to be conducted, of the employment as far as possible of immune native troops, of the employment of only seasoned Europeans, and similar matters already detailed, will have to be decided in the consideration of the general
strategy of a campaign. They are of vital importance, for a malarious country should never be invaded without counting the cost. The best medical advice on the subject should be solicited, and full weight given to any suggestions made. Prevention is always better than cure, and to avoid the disease in locality or in season is the surest form of prevention.

**Special Provisions.**

In the event of circumstances of extreme urgency making it necessary to inhabit a malarious country during the season of prevalence, it may be taken for granted that in the absence of adequate precautions an epidemic will be the inevitable result. As far as possible everything should be prepared in advance to combat this contingency.

Arrangements should be made for an adequate supply of mosquito nets. As the climate is such in most malarial countries that bivouacs will be the commonly used form of shelter, the bivouac mosquito net of the type described is the most suitable. This is issued at the rate of one per two men. A large reserve should be held available for the replacement of damaged nets. The men should be instructed in the use of these nets, and should have them issued and ready for use the first night they sleep within range of the mosquito. As the soldier is sufficiently loaded, arrangements must be made to have the nets carried by first line transport. A suitable repellent should be supplied for use under special directions. A sufficiency of quinine for all emergencies should be prepared.

In any but the shortest of campaigns screened huts should be provided as dining halls and recreation rooms for base units, and where practicable for permanent lines of communication posts. These are not luxuries but necessaries, and will more than pay for themselves. If base units can be housed in screened huts so much the better. If possible huts should be erected by the advance party.

All hospitals for the treatment of malaria should be of screened huts. It has been suggested that for small forces, where the number of sick and wounded is not high, two hospital ships should be used, one to be available for the reception of sick coming from the front, while the other conveys its complement of sick and wounded to the nearest healthy port.

A medical officer (or a team of officers in the case of a large campaign) with a special knowledge of malaria and entomology, should be selected and detailed to investigate the state of affairs and advise the Senior Medical Officer along the lines which will be indicated later. This appointment should be made as early as possible to allow schemes to be drawn out prior to the landing of the main body of troops. This officer should, of course, form part of the advance party if such can be sent.

Finally, some provision must be made for the early microscopic diagnosis of those cases which will inevitably occur. The clinical diagnosis of early malaria is by no means simple, especially where other fevers are occurring, and the only absolute diagnosis on the strength of which a patient can
be embarked on a prolonged course of quinine, is the discovery of the parasite in the blood. In Salonica mobile laboratories were available for this purpose. In Egypt, malaria diagnosis units were instituted, consisting of locally trained officers and orderlies equipped with the bare essentials for malaria diagnosis—slides, stains, a microscope, a tent, and a table [8]. Such a unit is a very economical and convenient one for malarial countries, and something along its lines should be provided where the more expensive mobile laboratory is not available. The number required would turn not so much on the number of troops as on the length of front occupied.

DUTIES OF THE ANTI-MALARIA OFFICER.

The first duty of this officer, on being informed of the country where the operations were to take place, would be to refer to the literature on the subject dealing with that locality for detailed information, first as to the type, severity, etc., of the malaria which occurred in that district, and secondly as to the local types of mosquitoes and especially those which were normally carriers. A key to the mosquitoes as far as known should be obtained from or through the Professor of Tropical Medicine at the Royal Army Medical College. Equipped with these details, and the apparatus necessary for entomological and malarial investigations, he should repair as soon as possible to the scene of operations.

He will, in collaboration with the sanitary staff officer, advise the general staff on the selection of sites for base camps, avoiding all localities likely to be unduly infested by mosquitoes, and those near native dwellings. Where for strategical reasons native villages cannot be avoided (if there is reason to suspect from the spleen index of the children that malaria occurs among them) the inhabitants should be cleared off to a safe distance and the village burnt. If the object of the expedition affords any choice of routes these should be investigated, and that which best conforms with the tenets laid down should be selected. Similar advice on the location of permanent lines of communication posts will be given.

Where the occupation of the base or lines of communication is expected to last some considerable time, the anti-malaria officer must consider the possibility of exterminating the mosquitoes by larva destruction. His first step in this is to ascertain what mosquitoes are carrying the disease and study their habits. If a specialized breeder, such as say \textit{A. stephensi}, is the cause of the trouble, the matter is simple and may be easily remedied, but if it is a marsh breeder such as \textit{A. maculipennis}, or a stream breeder like \textit{A. maculatus}, it may be almost an impossibility to stamp it out. In any case definite conclusions must first be formulated; the cost of a scheme certain (as far as can humanly be gauged) to be successful, estimated, and the advisability of the whole matter conscientiously reviewed. As a general rule, especially in small campaigns, it will rarely be possible to devise a scheme of larva destruction that is not outrageously expensive; in which
case the only conclusion to be drawn is that a similar result must be produced by some less costly method.

If, however, a scheme of larva destruction be decided on, the anti-malaria officer will advise the sanitary officer concerned of the steps to be taken. The actual work, whether draining or oiling or filling up pools or canalization of streams as may be decided, is best carried out by native labour supervised by N.C.O.'s of the sanitary sections. If the work is extensive the help of the Royal Engineers may need to be called on.

In the case of front line units it would only be in the most exceptional circumstances that the conditions given could be fulfilled and larva destruction on a large scale become justifiable.

Despite this it is always advisable to enjoin the destruction of breeding places which are actually in lines, or in their immediate vicinity; partly as a measure of policy and sanitary discipline, and partly because it will help to reduce the excessive numbers of insects liable to arise from such proximity, though it is unlikely to affect the malaria incidence.

**Prophylactic Quinine.**

Prophylactic quinine has so signally failed to prove its value during the late war that it must be ruled out of court as a routine measure for armies on active service. If, however, an unduly high malaria mortality were occurring, it might be given with a view to reducing this. Similarly it might be used for posts under circumstances where absolute control of administration could be ensured. The whole question could very profitably be investigated by well-controlled experiments. If given, the quinine should be in solution, and should be administered in doses of 5 to 10 grains about 18.00 hours each day. The strictest supervision must be exercised by the medical officer in charge to see that the dose is regularly taken.

**Duties of the Medical Officer.**

The medical officer will act as the adviser of the officer commanding the unit to which he is attached, and will keep in touch with the various anti-malaria measures that are being taken. He will keep accurate statistics of the cases of malaria occurring in the unit under his charge, and will try to trace the cause of any undue prevalence. He will satisfy himself that all recommendations made are being carried out, and will make representations where he has reason to believe to the contrary. He will in the absence of special recommendations from the anti-malaria officer advise on the site of camps, and will also indicate to the sanitary squad steps to be taken for the prevention of mosquito-breeding in or in immediate proximity to lines, and also as regards scrub cutting. He will instruct all ranks in the theory and the importance of malaria prevention, and will train men in the hand-catching of mosquitoes. He must be personally responsible for the administration of quinine given in the after-treatment of malaria. For this purpose a "malaria card" giving all the particulars of the attack, must be kept for each case, and must accompany
the man wherever he goes. On this should be entered from day to day the treatment, and by the use of this and a “quinine roster,” there should be no occasion for error or lack of continuity in dosage. Here as elsewhere results will be obtained by meticulous attention to detail.

MEASURES FOR ROUTINE APPLICATION.

Having dealt with matters which may or may not apply according to circumstances, we come to the method which is the bedrock of all active service measures of protection, and propose to formulate from it a set of rules for application under all circumstances. This is the method of protecting the individual from the bite of the mosquito. For many reasons this is the method on which to concentrate. It applies equally under all circumstances, and is as useful in the front line as at the base. It is not unduly expensive and does not involve much labour, for being a method in which a little work has to be done by everyone, a large total of work is done without any appreciable effort. It serves to keep apart both the healthy person and the infected mosquito, and the uninfected mosquito and the malarial person. It appeals to the men, for as well as preventing malaria it adds materially to their comfort. Lastly, but by no means least in importance, the responsibility for the execution of the necessary orders in connexion with it can be placed in the hands of unit officers, and any neglect can be made the subject of ordinary disciplinary measures.

The following set of rules is suggested for universal and routine adoption by all whom they may concern.

(1) Mosquito Nets.

These should be made of the standard fabric already described (30/8 cotton and twenty-five to twenty-six holes (trade counting) to the square inch).

There should be at least one standard pattern bivouac net to every two men.

Where bell-tents are used, one full-sized bell-tent net for each should be supplied, and the number of men per tent should be kept as low as possible.

A daily inspection of nets should be made, and all small holes kept carefully darned.

A margin of ten per cent of nets should be kept in unit stores to replace immediately nets which become seriously damaged.

Nets must be lowered half an hour before dusk, and after lights out an inspection should be made by the orderly officer to see that they are properly in position. Further, surprise inspections should frequently be made, and severe disciplinary action taken against offenders neglecting to use their nets properly.

Rest camps should be of screened huts or bell tents fitted with full-sized nets. The fringe of these must be weighted to keep a good contact with the ground, and there should be an efficient means of closing the door. A search should always be made for mosquitoes inside such a net before turning in for the night.
The Principles of the Prophylaxis of Malaria

(2) Protection between dusk and bedtime.

Shorts must be of the "turn-down" variety, and must be turned down half an hour before dusk.

Shirt sleeves must be turned down at the same time.

Mutual co-operation must be indulged in to brush off mosquitoes from hands and face. The use of hand fans should be encouraged.

Officers and nursing sisters must protect their ankles by thick hose or mosquito boots.

Full use must be made of screened huts where these are available.

(3) Picquets, Nursing-sisters, and others on Night Duty.

Either gauntlets and face-nets (e.g. the Simpsonette) should be worn, or repellants should be applied at frequent intervals.

In the case of picquets and guards the repellant should be issued to the N.C.O. in charge with orders regarding its application at regular intervals. As a rule two-hourly intervals will be sufficient.

(4) Killing of Adult Mosquitoes.

Each morning every man must search the dark places in connexion with his bivouac or tent or dugout for resting mosquitoes. These should be killed off with a "swatter."

In addition one man per company should be permanently employed going round these places and accounting for any that have been overlooked. If need be, this man can be trained to catch the mosquitoes in a bottle for examination.

(5) Special Measures which may be recommended by the Medical Officer.

The cutting of scrub for 200 yards round camps which are to be occupied for any length of time, and the treatment of collections of water in or in immediate proximity to such camps, will be undertaken by the sanitary squad augmented on occasions by fatigue parties as recommended by the medical officer.

In addition to all that has hitherto been suggested, there is one further element in the absence of which all these measures will be of little avail. That is the intelligent co-operation of the rank and file. By every means their interest must be stimulated—by lectures, by posters, and by propaganda of every kind. The subject is full of interest, and if lucidly expounded cannot fail to command interest. Special efforts should be made to impress the importance of the matter on junior officers and N.C.O.'s, as they have easy access to the men and can do much to influence them.

In conclusion, stress may once again be laid on the fact that results will be obtained not so much by the application of broad principles, as by scrupulous attention to detail in the methods employed. Malaria is a very vigilant and untiring enemy, and will not fail to use freely any chink which there may be in the armour of protection.
whole of the gut was carefully examined, but there was no evidence of ulceration at all.

Case 2. Indian 2/97 Deccan Infantry. Admitted to hospital with an irregular pyrexia and an enlarged liver and spleen. Blood films failed to show any malarial parasites, but instead a very definite polymorphonuclear leucocytosis was seen. Blood culture was negative and frequent examinations of the stools were repeatedly negative for cysts, etc. Needling of the liver failed to show any pus. The disease progressed more rapidly than

the previous case and terminated fatally. Emaciation was also more marked.

The post-mortem findings of this case were almost identical with the first case, with the difference that the liver was not nearly so large and the suppuration not so advanced. Cultures yielded pure growths of *B. coli*.

Case 3. Pte. W., British Army. This case was admitted to hospital with abdominal pain and pyrexia. A definite peritonitis developed. The abdomen was opened and pus found free in the abdominal cavity. The appendix was normal and there was no sign of a perforation. The liver was seen to be enlarged, but no obvious cause for the peritonitis could be found. The cavity was drained and the wound closed round a tube. The condition
of the patient did not materially improve, but gradually became worse and ended fatally.

Post-mortem examination showed about a pint of bile-stained purulent fluid in the abdominal cavity, together with a plastic peritonitis, matting the whole of the small intestine together. There was a right-sided fibrinous pleurisy at the base with marked diaphragmatic adhesions of recent origin. The liver was much enlarged and showed the same characteristics as the two previous cases. The condition had reached about the same stage as Case 2. The mesentery of the small intestine was shortened and the contained glands were in an advanced state of suppuration forming almost a single bag of pus. The small intestine was very congested, but was not perforated and neither that nor the large bowel showed any definite lesion. Spleen, kidneys, pancreas, etc., appeared to be normal. Cultures from the liver abscesses and the pleural pus gave pure growths of B. coli.

The post-mortem examinations in Cases 1 and 3 were performed within eight hours of death and in Case 2 just over twelve hours.

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A CASE OF INFECTIVE ENDOCARDITIS DUE TO PFEIFFER'S BACILLUS.

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The literature of influenza contains comparatively few references to endocarditis as a complication. McCallum, in his study of pneumonia in the U.S. Army Camps in 1917-18, records only two cases of infection of the endocardium out of sixty post-mortem examinations. One was a pneumococcal infection of the aortic valve, and the other probably a streptococcal infection of the mitral valve. He quotes one case from Mallock, in which Pfeiffer's bacillus had been recovered post-mortem from the heart vegetations. The Medical History of the War states that the endocardium was rarely affected in post-mortem examinations of fatal cases of influenza, but mentions Mallock's cases, and the fact that one or two others had been reported. On the other hand, Sir Thomas Horder, writing in Price's "Medicine," definitely mentions Pfeiffer's bacillus as a cause of infective endocarditis, and states that in forty cases of this disease in which organisms had been grown from blood culture taken during life streptococci were found in twenty-six cases, pneumococci in five, Pfeiffer in five, gonococci in two, staphylococcus in one and an unclassified bacillus in