THE FLY AND MOSQUITO AS CARRIERS OF DISEASE.[a]

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GENTLEMEN: In responding to the invitation of your secretary to address you upon the subject of The Fly and Mosquito as Carriers of Disease, I feel that you have assigned to me a duty at once important, in that it embraces the consideration of the results of observations of men of eminence during the past few years; honorable, in that it is a subject of the deepest significance and requiring the most patient scientific investigation; and pleasant, in that it shows the confidence reposed in me as an individual in exemplifying the work of others.

Allow me to reverse the order in which the subject was presented upon the programme and first take up the subject of the mosquito as a transmitter of disease. Within less than a decade this subject has assumed the greatest importance, as up to that time, in fact, even to a later period, the transmission of the disease now recognized as being conveyed by the mosquito was laid down as one of those puzzling problems, the pathology and etiology of which were incapable of explanation.

In a body of this character it is unnecessary for me to say that diseases for the transmission of which the mosquito at the present time is held responsible are: First, malarial diseases; second, filariasis; and third, yellow fever, with a new candidate for consideration as represented by the trypanosomes, the importance of which has only been recognized since the acquisition of territory in the Far East as a result of the war closed within the last few years. Naturally malaria must occupy most of our attention. This is perfectly natural, not only from the widespread existence of malaria, but from the influence which malaria has had upon the history of the civilized world. There is probably no influence so potent in preventing the extension of explorations and the opening up of new regions as the prevalence of this disease, which we have always with us in more or less mild form, and which in certain sections of the world assumes a virulence that to the uninitiated is simply terrific. No one influence, it may be again remarked, has so militated against the successful opening of the Tropics to commerce as this ever-present scourge. African explorers have found no enemy so dangerous as the terrible fevers that exist in the interior of the country, and it is only within the past few years, aided by the researches of men such as Laveran, Bignami, Marchiafava,

[a] Read at the meeting of health officers of Ohio, Columbus, Ohio, January 29–30, 1903.

Ross, Manson, and a host of others too numerous to mention, that there appears to be a probability of the stumbling-block being removed.

No one is free from the danger of malaria in almost every section of the world, and Koch justly says:

> Malaria is met with everywhere. The officer in his bureau, the traveler in the interior, the soldier upon the march, all must recognize that sooner or later they are to become the victims of malaria.

No more important discovery stands as a milestone upon the road to progress than the original discovery by Laveran of the malarial parasite, removing the disease from that vague, indefinite sphere of an unknown entity combating human happiness, which is well intimated in its name derived from the Italian of "bad air" and signifying that it was an emanation of miasm, insidious in its methods of entrance and potent for evil in its effects upon human beings. Even after the discovery of Laveran of the nature of the infecting agent in malaria there remained much doubt as to the way in which it effected entrance into the human economy.

Malaria has been regarded for centuries as an air-borne disease, as indicated by its name. When general recognition had to be given to the almost axiomatic fact that for every disease there is a tangible cause, the plasmodium of Laveran answered to the causative agent; but there was no solution to the question for a long time as to how this parasite was conveyed from its ordinary habitat into the body of the unfortunate victim who became the subject of his chill, his paroxysm of fever, and of his stage of sweating. It was thought for a long time that the parasite was borne upon the miasm arising from swampy districts, thus effecting an entrance into the economy through the respiratory tract. This theory failed of scientific demonstration. Again, it was believed, and for a long time seemed susceptible of proof, that the parasite was ingested along with the water drunk, and passing into the intestinal canal, there underwent multiplication and entered the great circulating fluid—the blood—and by its cycles of maturation caused the outbreaks.

Thus the matter rested until attention was directed to researches of Dr. Patrick Manson, who took the advanced position that an intermediate host in the shape of a certain gnat or mosquito was necessary in transmitting the disease from man to man and was also an inevitable portion of the cycle of the development of the parasite. No subject has been more carefully and elaborately worked out; in no research known to modern science have fanciful or theoretical deductions been the subject of more careful scrutiny; and to-day the "mosquito theory" of the transmission of malaria is no longer a theory, but an accepted fact, and while it is impossible to say that it is the only responsible agent for the entrance of the malarial parasite into the human economy, it certainly answers all of the indications required by the most critical scientific mind and bears every test applied to it.

The Italian observers several years ago demonstrated the fact that it was perfectly possible to convey malaria from one individual to another by an injection into the circulation of the subject to be experimented upon of blood from a person suffering with malarial paroxysms; but it was immediately demonstrated that such paroxysms, while typical, soon passed off and did not have that virulence and persistency that characterize the disease when acquired through natural channels. It would be a matter of too much time to reiterate here how, step by

step, Manson, Ross, and others were led up to the deduction that for the maturation of the malarial parasite in full virulence an intermediate host was necessary. No more interesting chapter of scientific literature could be laid before you for consideration at this time; but even to enter into the alphabet of the subject would demand an amount of time which would impose upon your good nature. To follow out the question thoroughly you must be referred to the literature upon the subject, which now has become historical. Suffice it to say that it would appear that for the perpetuity of malaria it is necessary that the parasites should be introduced into the body of an insect host and there undergo elaboration and multiplication, and at a certain period of the cycle of development should be injected by their intermediate host into the circulation of the human being, there to undergo further modification and to acquire their full virulence in the unfortunate individual who has been the subject of the bite of the insect host.

Experiments have demonstrated beyond cavil that not only is the mosquito the responsible agent, but that one single genus of the mosquito family is the host, by election, for the maturation and proliferation of the malarial organism. The ordinary mosquito of the genus *Culex* is quite harmless in this respect. These mosquitoes are a pest, a nuisance pure and simple, but their occurrence in a locality is without pathological or etiological significance. For the successful propagation and transmission of malaria a certain family of mosquitoes—the genus *Anopheles*—is necessary. Many varieties of *Anopheles* are known—the *Anopheles claviger*, *Anopheles maculipennis*, and the *Anopheles nigripes;* but it may be said in general terms that one of the family of "spotted-winged mosquitoes" must be present to constitute an essentially malarial neighborhood or environment.

The mosquito doctrine is not a new one. Nuttall states that nearly two thousand years ago the Roman writers Varro, Vitruvius, and others indicated that mosquitoes bore a casual relation to malaria. Knott referred to it in 1848, and King in 1883 wrote an elaborate argument in its favor. But it is to Manson, of England, that the credit belongs for a reawakening of an interest in the subject, and in his Goulstonian lectures, of 1898, he followed the hypothesis which, after much discussion, much work, much acrimonious and polemic theorizing, has now been accepted as true; and it is not too much to hope that with a thorough knowledge and acceptance of the dictum as laid down by all these investigators, the names of some of whom have been given to you in the early part of this address, the suppression of malaria, the deadly foe of mankind, will be a matter of accomplished fact and that the march of civilization will proceed without encountering the terrible difficulties which have heretofore beset its path.

I will detain you for a few moments only to give you a very brief outline of the course of development of the malarial parasite within the body of the mosquito, taking the aestivo-autumnal form as a type.

The process of the development of the malarial parasite in the mosquito is evidently a sexual one, and takes place in the middle intestine of the insect; and, being sexual, there must be two agents concerned in it, which are respectively the crescentic body and the passive nonflagellated female elements known as macro-gametes. The crescents themselves are known as gametes, and the male elements or active flagellated bodies as micro-gametocytes and the nonflagellated or female elements as macro-gametes. Let us suppose that a person suffering

with malaria in whose blood the crescentic organism is demonstrable has been bitten by one of these mosquitoes. If the middle intestine of a mosquito is examined within forty hours after she has bitten, the intestinal wall will be found to contain numerous spindle-shaped bodies identical in appearance with those observed in the human blood, but slightly larger in size. The bodies are pigmented, but the pigment, instead of being formed in a clump, or scattered as in the case of human blood cells, is ranged round the periphery. The bodies are situated on the outside of the epithelium and basement membrane of the intestine, between it and the muscular wall; that is to say, they are within the substance of the intestine.

From the second day developmental changes become very rapid and by the third or fourth day it will be seen that the bodies have very much increased in size and that the protoplasm has become granular. On the fifth day the increase in size has proceeded to a remarkable extent, the parasites becoming so large that they project from the intestinal wall like processes which contain numerous minute bodies that are nuclei, and shining particles resembling fat. On the seventh day the interior of the parasite contains an immense number of very delicate filaments which contain at the center a small amount of chromatin and are arranged like rays about a central mass, which may or may not contain some black pigment. These filaments are the sporozoites. After the seventh day it will be found that the capsule has ruptured, setting free the sporozoites, which now make their way into the tubules of the salivary glands, which will be found to be crowded with the parasites, and these, inoculated into man by the biting of the mosquito, undergo certain and as yet undetermined changes and become the hyaline, intracellular malarial parasite.

The cycle of the malarial organism may, therefore, be summed up into two great stages—the human cycle and the mosquito cycle—which may be described as follows:

The human cycle in five stages:

1. Sporozoite.
2. Hyaline body.
3. Pigmented body.
4. Segmenting body.
5. Crescentic body.

Taking up the study where we left it, therefore, we pass into the mosquito cycle, which also has five stages, viz:

1. The crescentic body, or gametes.
2. The round passive body, or macro-gametes.
3. The round, active, flagellated body, or micro-gametocytes.
4. The encapsulated cystic body.
5. The sporozoite, again ready to enter the human economy through the instrumentality of the bite of the mosquito.

I am conscious, gentlemen, that this is the barest outline, so bare a skeleton that I am almost ashamed to present it; but, as has been before remarked, the time at the disposal of this gathering will not permit a more elaborate exemplification of this most interesting process.

It may be asked: What bearing does this have upon the question of malaria as it affects us as county, city, and village health officers, almost all of whom are practicing physicians? What influence do the description given and the researches enumerated have upon the well-being of the communities and the patients intrusted to our charge?

What practical deductions are to be drawn from these highly interesting philosophical demonstrations? The reply is that, as surely as night follows day, so surely will the destruction of mosquitoes of the genus *Anopheles* in a given locality be followed by a marked diminution of the malarial disease, and with the entire destruction of the insect pests by an entire disappearance within a short time of cases of malarial manifestations.

Therefore what has been presented to you is not simply a scientific discussion of historical interest, but it affects physicians, their patients and communities under their charge in an eminently practical way. The lesson to be drawn is, that in a malarial community the main object should be to strike at the root of the evil by the destruction of the mosquito responsible for the transmission of malarial disease from man to man. When it is remembered that a single female *Anopheles* may, after biting an individual affected with malarial fever, set free millions and millions of sporozoites and may infect with malaria every individual whom she bites, that she lays a large number of eggs and that a large proportion of these eggs come to maturity, thus producing a new crop of mosquitoes ready to bite other individuals, it will be seen that the process is like the endless-chain letter system, which, beginning with one individual, will in time unless checked reach an almost countless number.

Mosquitoes should be destroyed wherever found, and no surer way exists of destroying them than to prevent the ovidepositing of the females. Water is the essential element required in this ovidepositing. The female must have a larger or smaller body of water upon which to deposit the wonderful canoe-shaped mass of eggs that she lays. Therefore the filling up of all stagnant pools of water, the drainage of large bodies of water, the abolition of water barrels, the screening of cisterns, even the emptying of the old tin can about premises which may contain rain water, are all essential steps in the mosquito campaign, and it is by a campaign against the mosquito that we must arrive at the suppression of malarial disease. Should the ovidepositing of the female have taken place, means must be adopted for the destruction of the ova or the larvæ and pupæ, should they have passed into these stages. No other agent is probably so effective in this direction as the use of petroleum upon ponds or bodies of water, should it be impossible or not feasible to drain them thoroughly or fill up with fresh sand their original site.

Remember that, taken in conjunction with each other, a person afflicted with malarial paroxysms in a locality where any variety of the genus *Anopheles* prevails is reasonably certain to spread the malarial disease throughout the community.

The most interesting and vital branch of the subject, gentlemen, has been dwelt upon at such length but that little time remains to take up the other disease for the transmission of which the mosquito is responsible. Therefore I omit any mention of filariasis or trypanosomes and pass on to briefly discuss the mosquito theory of the transmission of yellow fever.

Unfortunately, unlike malarial disease, the parasite of yellow fever has not been demonstrated, and until this is done we can not approach the subject with that certainty with which we can describe malarial fevers. This only is known: That, unlike malarial diseases, the genus *Anopheles* of the mosquito family is not responsible for its transmis-

sion; but the transmitting agent is the female of that family, known as the *Stegomyia fasciata.* Possible it is that time and further study will develop the true parasite of yellow fever, and that its life history and method of transmission may at some future time be described as minutely and as accurately as has been done in the outline which has been laid before you.

The theory originally propounded by Finlay, of Habana, lay fallow until taken up by that quartet of earnest workers—Reed, Carroll, Lazear, and Agramonte. Lazear fell a victim to his enthusiasm, and may be said to have laid down his life for the cause in which he was so deeply interested. Reed has joined the silent majority, and when, in the future, the hypothesis so ably maintained by him shall have acquired all the force and dignity of a doctrine, the subject can not be approached or written on without a tribute of love and reverence to his memory.

With the full knowledge that the subject has been very imperfectly touched upon, and spurred on by the lapse of time, we must rapidly pass on to the consideration of the second branch of our subject, viz, diseases transmitted by flies. The subject, while not as complex as the one of the mosquito, is still full of interest; but we will limit our consideration to two diseases, potent in vastness and fraught with the direst calamities to humanity. One of the two diseases will be that great epidemic pestilence which from time to time devastates whole regions of the Orient, and from which in times past the United States itself has not been free, viz, cholera.

As far back as 1890 it was demonstrated that the ordinary house fly could carry within its intestinal tract live cholera vibrios; that they could there multiply and could be deposited in the fecal excreta of the fly either upon water or upon the food, and thus under favorable conditions become the responsible agent for the spread of the infection. The matter has an obvious practical bearing for the consideration of a gathering of health officers, for it may be taken as practically evident that cholera is not alone a water-borne disease, but that our measures of precaution and safety are not completed until we have effectively assured ourselves that flies do not have access to the discharges of a cholera patient; or, if such be impossible, that these discharges are rendered innocuous by efficient disinfection. Therefore the disinfection of the discharges of a cholera patient not only is demanded in order that the water supply may not become contaminated, but having the further end in view that, should the domestic house fly feed upon them, it may not through its intestinal canal contaminate the food and drink of others.

Let us rapidly pass on to a consideration of the fly in the dissemination of typhoid fever. During the Spanish war a committee of medical officers was appointed by the Surgeon-General of the Army to investigate the subject of enteric fever in the military camps, and in an admirable report they arrived at certain conclusions, which were the specificity of the Eberth bacillus, the influence of infected water in spreading disease, and the great danger attending the instrumentality of flies in disseminating the Eberth bacillus by feeding upon typhoid dejections and thus contaminating food and drink upon which they might alight. The lesson borne in upon us, therefore, is the same as in the consideration of cholera—the absolute disinfection of all discharges, alvine, urinary, and buccal, of the typhoid patient, for these

discharges all do, at one time or another during the occurrence of a case of typhoid fever, contain the responsible Eberth bacillus and, subjected to contact of flies, may through the instrumentality of this disgusting pest be responsible for the spread of the malady to persons at greater or less distance. In this, as in every other communicable disease, eternal vigilance is the price of safety.

No more serious subject can occupy the attention of a careful health officer, and the health officer who simply guards the water supply from contamination, great though his results may be, can no longer be regarded as having performed the full measure of his duty. He must look after the fly. It should be excluded from the rooms of the sick; it should not be permitted to gain access to any of the discharges of the typhoid patient. Though in guarding the water supply the health officer may have closed the most important opening, the neglected minor precaution leaves a gap, and, to use a well-worn axiom, "the strength of a chain is the strength of its weakest link," until he has paid as much attention to one source of danger as to another his chain of defense is not perfect, but may give way at the weakest point.

At a meeting of the Association of Military Surgeons of the United States, recently held in Washington, D. C., the writer had the honor of presenting a paper upon "The prophylaxis of certain diseases incident to camps in time of war," in which he took the position that, to guard against the appearance of typhoid fever in the future, certain points should be taken into consideration, which were as follows:

1. Early recognition and positive diagnosis.
2. Absolute disinfection of the discharges of all hospital febrile cases.
3. Rigid policing and disinfection of all camp latrines.
4. Guarding of water supplies from infection, not only by careful prevention of direct contamination but by foresight in the location of latrines in relation to the sources of water supply.
5. The employment of every possible means to prevent the multiplication of flies and the infection by them of kitchens and messing places.

It was also suggested that in future it would be wise to consider every case of enteric fever as an "infectious case," and to treat them in a special hospital provided for the purpose and not in the general wards of a military hospital.

So important, gentlemen, is this subject of the transmission of enteric fever that it would seem in the future we should lose no opportunity of profiting by the terrible lessons that have been taught in the past. This applies not only to military operations. In the future it would seem wise that where there is to be any large aggregation of persons for a long period of time, a preliminary period of observation under conditions approaching those obtaining in camps of detention should be practiced before the individuals be allowed to assume the new duties which may devolve upon them. This period of time, it is suggested, should be for the period of the incubation of the disease, and every case of illness or indisposition should be thoroughly investigated with a view of excluding possible cases of enteric fever and enabling us to take the proper precautions in handling them. This period of observation completed, the individuals may then pass from detention camp conditions to conditions and environments as are necessary for the object in view, be these objects military, civil, political, or social.

Another point which has been suggested by Surgeon-General Wyman

and which does not seem as yet to have been mentioned, or if mentioned has not as yet been printed, is that in future in all such large gatherings the latrines or other provisions for the disposal of personal dejecta should be rendered fly-proof by screening with wire netting. This may appear a stupendous task; but were the difficulties even greater than they really are, it is believed that the end would justify the means and that we would reap an abundant harvest of good. In camps the capacity of latrines is carefully calculated upon the basis of the number of persons for whose use they are intended. It would seem that large supplies of wire netting upon wooden frames should acccompany the camp equipage and that at the time when the latrine is dug the screen frames should be erected and the latrine thus rendered fly-proof from its very inception. This "fly-proofing" should be carried to the most rigid extreme, even to the extent of rendering entrances impermeable to flies by an arrangement of vestibules or double doors. Having accomplished this end of excluding flies, the most rigid precautions should be taken to insure the covering and disinfection of the dejecta, and when the trench or pit is filled to the depth determined upon the screen can be taken down and removed to a new site.

In the disinfection in camps against typhoid fever attention is invited to a procedure mentioned by Major Griffiths, who states that much good resulted in his practice in such disinfections from disinfecting not only the tent or temporary habitation where a case of enteric fever had occurred, but in extending this disinfection rigidly to three or four tents upon each side of the one represented to be infected. This would seem to be based upon the presumption that the fly does not indulge in long flights, but having selected a locality agreeable and suitable to himself he never departs far from it. In this way it would certainly seem that there might be a certain limitation to the dissemination of the infection of enteric fever.

I feel, gentlemen, that I have presented to you, in a very imperfect way, views upon the topics which form the subject of this paper. Much more could be said; little has been said in comparison with the amount of material at the command of one looking up the subject. While I may have conveyed to you nothing original, it may be that the subjects presented will lead one of you to research and to an endeavor to secure better results. If such be the case, the time spent by you in listening to these remarks of mine and the labor expended by me in presenting them to you will indeed have been a source of pleasure for me and, I trust, a source of some profit to you.

NOTE.—For the description and classification of the life cycle of the malarial parasite, on page 6, the writer is indebted to the work of Asst. Surg. Charles F. Craig, U. S. Army, entitled "The Estivo Autumnal Fevers."