HOUSE-FLIES AS CARRIERS OF DISEASE.

THE discovery of the rôle of insects in the transmission of human and animal diseases is one of the most striking achievements of medical science during the last twenty-five years. Filariasis, Texas fever, nagana, malaria, sleeping sickness, yellow fever, dengue, sandfly fever, relapsing fever, plague, typhus, and many other diseases of the lower animals, have been shown to be transmissible by blood-sucking insects—mosquitoes, ticks, tsetse flies, fleas, or lice, as the case may be. The pioneers in this line of inquiry were Manson, Smith and Kilborne, Bruce and Ross.

In a number of cases the necessity of intervention by an insect has been established by the discovery that a portion of the life cycle of the parasite is passed in mosquito, tick, or tsetse fly respectively. In other cases, the evidence rests upon the correspondence in time and space of the incidence of the disease with the presence of some particular insect which has been experimentally shown capable of transmitting the infection. In yet other cases, such as plague, the microbe can also pass directly from patient to patient, as happens in the pneumonic variety of the disease, but the paramount importance of flea transmission in bubonic plague gains in recognition daily.

The rich harvest of discovery reaped by the investigations into the part played by blood-sucking insects in the spread of the above-mentioned diseases naturally stimulated inquiry into the possibilities of insect carriage as a factor in outbreaks of cholera, typhoid, dysentery, and epidemic diarrhœa. These are not diseases in the transmission of which a blood-sucking insect is likely to play a part, for in none of them is the infecting microbe present in the blood-stream in sufficient quantity, but the dejecta, fæces, and often urine, contain the bacilli in countless numbers. A small proportion of convalescents continue to excrete them for weeks, months, and, in the case of typhoid, for years afterwards, although enjoying perfect health. These people are particularly dangerous to the community as they form an unsuspected reservoir of infection.

To produce an epidemic of typhoid, cholera, or dysentery, the bacilli dejected by persons sick or convalescent from the disease must find access to the alimentary tract of others. There are, however, ways in which this may happen independent of the agency of insects. A water supply may become contaminated with infected material; the dejecta may dry up and be distributed as dust, and fall upon food materials (a method, the importance of which may easily be exaggerated, as these bacilli are readily killed by desiccation), or, owing to bacteriologically inadequate attention to cleanliness, food-stuffs, in which the microbes can multiply, may be infected with bacilli from patients or convalescents. Typhoid and cholera bacilli are small objects, less than one-thousandth of an inch in length, so that fingers may be easily soiled by considerable numbers without this being obvious, and the microbes are not removed by perfunctory washing.

Although these three means of spread do produce and maintain epidemics, one has but to consider the habits of the house-fly to realise that this insect may be an able and willing assistant in the distribution of the bacilli which are the cause of cholera, typhoid, dysentery, and diarrhœa, and that flies, if in sufficient numbers, and under conditions favourable for their operations, may constitute the principal way in which infection is distributed. In order to appreciate how this may happen it is necessary to be in possession of some few points in the life-history and structure of the fly.

These subjects have been submitted to careful inquiry during the last few years, particularly in America and this country, by Newstead, Howard, Griffith, Hewitt, and Graham Smith, and we are now well acquainted with this insect, intimate knowledge of which was, until recently, curiously lacking.

The female fly lays about 120 eggs at each laying, and may produce four broods. The eggs are mostly laid on horse manure or other fermenting refuse; they are about 1·5 mm. in length and 0·3 in their greatest diameter, and hatch in from three days to eight hours, according as the temperature ranges from 50° F. to 80° F. The larva is a little active grub 2 mm. long; and on hatching out burrows into the manure or other material on which the eggs are laid. The larval stage lasts five days to three weeks, and pupation five days to a month, according to temperature. Thus the whole cycle from laying of the egg to emergence of the fly occupies ten days to two months, according as the weather be warm or cold. The young female is ready to lay its first batch of eggs in about ten days, or even sooner in warm weather. Owing to this influence of temperature upon the rate of development of egg, larva, pupa, and imago, the number of flies in August depends on the temperature during June and July.

During winter a few flies survive in warm and secluded places. In the spring these start the next year's supply. Dr. Howard, of the United States Department of Agriculture, estimates that in forty days the descendants of one fly might number twelve million, or 800 lb. weight.

It will therefore be obvious that any attempt to overcome the nuisance from flies must, if success is to be achieved, be directed to their breeding haunts, and as early in the season as possible.

The points in the anatomy of the fly of importance for our present object are the legs and feet and the alimentary apparatus. These will be sufficiently obvious from the diagrams (Figs. 1 and 2). The feet are covered with minute hairs, which are more numerous and finer than in the diagram, and extremely fine hairs are also placed upon the pads. A sticky substance is secreted by the surface of the pads, by means of which the fly grips. Each leg is like a minute paint brush, which is applied to the surface of whatever it rests upon, excrement or food-stuff, as opportunity offers.

The alimentary canal comprises a gullet, stomach, crop, intestine, and rectum (see Fig. 2). The gullet is prolonged forwards to a minute opening between the flaps of the proboscis, half-way down which it is joined by the salivary duct (S D). At the entrance to the stomach (S) it is bifurcated, and one limb of the bifurcation is extended backwards to the bilobed crop (C). By a valvular apparatus at the entrance to the stomach, the insect can direct the liquid driven by the pump in its trunk into either the stomach or crop. The proboscis is a highly elastic muscular organ with universal movement. At the end are two flaps

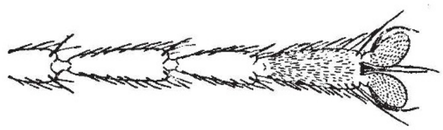

FIG. 1.—Leg of a house-fly.

or labella (only one of which is shown), which it can open out like the leaves of a book, and apply the medial surfaces to the material it feeds upon. From the middle line or hinge, minute chitinous channels pass outwards to the margin. At the base of the trunk a number of muscle fibres are attached to the gullet by the peristaltic contraction of which fluid is pumped up from the mouth and propelled into the stomach or crop. The structural arrangement of the channelled flaps of the trunk acts as a filter, through which solid objects larger than 1/4000th in. seldom pass. When feeding on a liquid, the fly applies the labella to the surface, and sucks the liquid through the

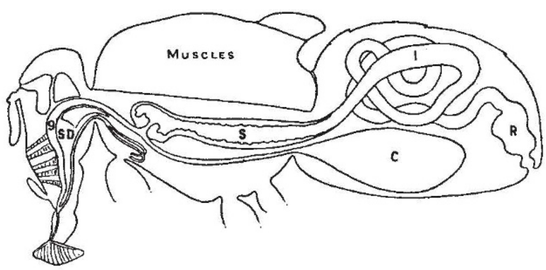

FIG. 2.—Alimentary system of a house-fly.

"strainer" first of all into the crop. When this is full, a further quantity is admitted into the stomach. In the case of solid material, such as sugar, the insect must first dissolve the material. This is done by pouring saliva upon it, or by regurgitating some of the contents of the crop.

A well-fed fly deposits fæces abundantly, and also the contents of its crop upon sugar and other solid objects.

It is clear, therefore, that there are *a priori* reasons for suspecting the fly of carrying bacterial infection. Born in a dunghill, it spends its days flitting between the sugar basin, milk pan, and any fæcal matter available. Its hairy, probably sticky, feet and the habit of regurgitating the contents of the crop and defæcating at frequent intervals, suggest it as an excellent inoculating agent for any bacteria it may pick up in the satisfaction of its catholic tastes. That it does, indeed, operate in this way has been abundantly demonstrated. Flies which have wandered over cultures of organisms and afterwards been allowed to walk upon gelatin plates leave a rich crop of germs in their footprints, which can be demonstrated by subsequent incubation.

Flies fed in the laboratory upon material containing easily identifiable pathogenic microbes have been shown to harbour them in their crops for days, and to deposit them in their fæces and the regurgitations from their crops. Internal carriage is probably more important than soiling of the exterior of the insect, as many pathogenic bacteria soon die from desiccation on the appendages of the insect.

In addition to these laboratory experiments, there are numerous recorded instances in which the pathogenic organisms of cholera, typhoid, phthisis, anthrax, and plague have been recovered from the interior or dejections of flies which have been captured in the immediate neighbourhood of cases of the disease, or, in the last two cases, of carcases of animals dead of the disease.

Although, however, flies may be discovered with the infection of a number of diseases in or upon them, and by their habits may not unlikely serve as agents in transferring infection, it by no means follows that they are the determining factor of epidemicity in the case of cholera, typhoid, dysentery, etc. In the case of fulminating epidemics of typhoid and cholera associated with an infected water supply, this is obviously not so.

It is in temporary encampments of troops or pilgrims, when the disposal of excreta must necessarily be of a primitive character, that the conditions obtain which are most favourable to the breeding of flies and the distribution of infection by them, if cholera or typhoid appear. Even in these circumstances it is difficult to assess the relative importance of fly carriage and other means of spread, but the conclusion that fly transmission is the principal means of spread of typhoid in military encampments and stations has been arrived at by a number of competent observers, amongst them the commission to inquire into the origin and spread of typhoid fever in the United States military camps during the Spanish war of 1898, and by a number of medical officers concerned with the severe outbreaks of enteric which occurred during the Boer war.

The sanitary arrangements of a military camp are not exactly those of the Ritz Hotel, and the prevalence of flies in late summer can scarcely be appreciated by those who have not had camp experience. The conditions are most favourable for transmission of disease by flies, and the circumstantial evidence against them is so strong as to have left no doubt in the minds of the American Commission that these insects play a large part in disseminating infection, for on page 28 of their general statement and conclusions we read:

"Flies undoubtedly served as carriers of infection."

An estimate of the fly population and its relation to admissions for enteric fever was made by Ainsworth in Poona, where enteric has a very definite season. A definite number of fly traps was set, and the daily catch taken as a measure of the fly population. The observations showed that the abundance of flies increased earlier than the admissions for enteric, and, speaking generally, the rise in fly population ante-dated the rise in enteric cases by about one month.

Taking into account the incubation period for the disease, this fact is in agreement with the view of a causal relation between cases and flies in Poona.

In considering the possible influence of flies in the spread of typhoid in a well-sewered city, it must be remembered that the opportunities for them to pick up the infection are vastly fewer than under the conditions of a military encampment, or even in rural surroundings. In large cities with modern sewerage, dejecta and urine from patients may be left available to flies, but the bulk goes promptly into the main drain, and similar observations to those above-mentioned have shown no close relationship, in point of time, between cases of typhoid and prevalence of flies in London, Washington, or Manchester.

As with typhoid, the case against flies as agents in the distribution of the infection of cholera is circumstantial, as other means of spread cannot be excluded. Take, for instance, the case of an accumulation of 300,000 pilgrims in Puri, India, in July, 1912, which was studied by Greig. The sanitary accommodation of the town was inadequate for such an accession to the population. Some of the pilgrims imported the infection of cholera, and an outbreak occurred. Flies in Puri "amounted almost to a plague," and a bacteriological examination of the legs and the contents of the alimentary tracts of flies caught in the neighbourhood of cholera cases demonstrated the presence of cholera vibrios.

Knowing the habits of flies, it is impossible to forgo the conclusion, arrived at by Greig, that some amount of distribution of the infection of cholera was due to their activity. But to what extent they were contributing could only be ascertained by the result of measures directed either to the diminution of their numbers, or to depriving them of access to infectious material.

Greig could not supervise the private latrines of the native inhabitants, but was able to carry out practical measures to prevent flies from visiting dejecta in the case of an outbreak of cholera amongst a limited population in the Puri jail. These were attended with immediate good results.

There are the same general reasons for assuming that fly transmission plays an important part in epidemics of summer diarrhœa of infants as in the case of typhoid and cholera. Anyone familiar with the domestic *ménage* of the average working man on a hot summer day, with the baby sick with diarrhœa, and other small children to care for, must realise that the opportunities afforded for flies to transport the infective agent from the dejecta of one child to the food supply of another are more than adequate.

Epidemic diarrhœa of children does not occur except during that season of the year when flies are abundant and active, and, as will be seen from the accompanying chart, the relation between fly population and diarrhœa cases is so

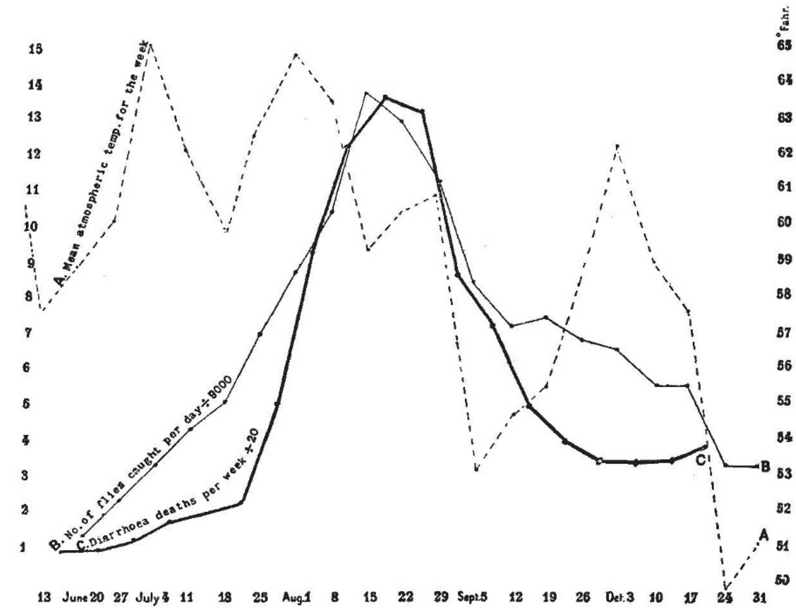

FIG. 3.—Dr. Hamer's observations on relation in point of time between prevalence of flies and diarrhœa mortality in London, 1908. (141 fly-collecting centres.) The deaths from diarrhœa have been antedated 10 days

striking as to suggest something more than a mere accidental dependence upon the same phenomena.

The chart is constructed from Dr. Hamer's observations on the numbers of flies caught daily in the same number of traps in 141 localities in London during 1908. An important point brought out by these observations is the dependence of both the number of flies and the epidemic upon the cumulative effect of previous warm weather—as, for instance, is indicated by the earth temperature four feet below the surface, a fact to which attention was directed by Ballard in 1889. Similar observations in Manchester, by Dr. Niven, in 1904 to 1906, showed the same relationship.

The reason why the number of flies should be dependent upon this factor is obviously that the generation time (cycle from egg to egg) is dependent on temperature, and requires three weeks or upwards in our climate. Months of warm weather are therefore required to produce any multitude of flies from the few surviving in the winter. Why the epidemic should exhibit this dependence is not explained, unless on the assumption that the fly population determines the number of cases of diarrhœa.

Without losing sight of the various other ways in which the specific infective agents of cholera, typhoid, epidemic diarrhœa, and dysenteries may be and are transported from the excreta of one individual to the mouths of others, the *prima facie* case against the house-fly is complete.

Further, in the case of infantile diarrhœa, the fly-carriage hypothesis offers a satisfactory interpretation of the extraordinary dependence of the epidemic upon the accumulated effect of temperature, and affords a ready explanation of the spread of the infection of cholera, typhoid, and diarrhœa to neighbouring persons who have no contact with the patient, in those cases in which contamination of a water or food supply may be excluded.

The direct proof of the extent of the danger due to flies is lacking, but the hypothesis has pragmatic value. It not only interprets facts otherwise awkwardly explained, but measures based upon it have been attended with beneficial results; in other words, it works.

THE RESURRECTION OF BABYLON.[1]

THOUGH scarcely a book to attract the general reader, Dr. Koldewey's account of the German excavations on the mounds which have for ages entombed the remains of Babylon the Great, is a work of considerable importance for all who are interested in the archæology of the Old Testament. This, as perhaps is not generally known in England, is still a growing science; and the worst thing that can be said of the German Expedition to Babylonia is that, after so many years of patient and persistent spadework on one of the most promising sites in the world, it has not yet succeeded in unearthing anything of higher historical or religious value than is recorded in the volume before us. Nothing extraordinary has hitherto been found; no great literary monument, no document of supreme religious moment, nothing that lends decisive help towards the settlement of any one of the unsolved problems of history or chronology. How much more fortunate in this respect were the pioneering labours of Layard and George Smith and Botta at Nineveh, of Rassam at Sippara, of De Sarzec at Tellô, of De Morgan and Scheil at Susa!

It is well for us that the Assyrian kings were so deeply interested in the literary monuments of Babylon. Had we depended for our knowledge of these on the remains of the Great City itself, we should (until the recent American discoveries at Nippur) have been left without any indication of the existence of the Babylonian legends of Creation and the Deluge; to say nothing of the many relics of the arts and sciences of Babylon which the library of Assurbanipal preserved for us.

The pathos of the position of the German explorers was that the site had been looted so often previously to their systematic investigations that scarcely anything of first-rate importance was left for the latest adventurers. The temples and palaces of Nebuchadrezzar's capital were probably swept bare of most of their portable treasures at a comparatively early period; and the ravages of people in search of building material, and the petty pilferings of Arabs and other stray visitors, had doubtless robbed the ruins of much that would have been priceless in the eyes of modern explorers. Even the beautiful enamelled bricks,

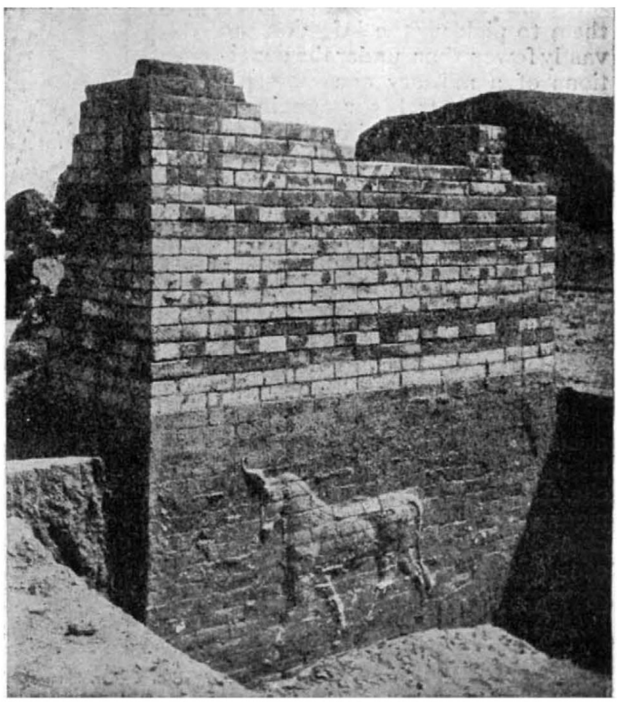

FIG. 1.—Enamelled wall length of the Ishtar Gate. From "The Excavations at Babylon."

with their strange mythological figures, are not altogether a novelty. Older specimens of the same kind of mural decoration were long ago reproduced by Perrot and Chipiez from Sargon's palace at Khorsabad ("History of Art in Chaldea and Assyria," II., plate xv.; see also plates xiii–xiv. Eng. Trans., London, 1884). But it is highly satisfactory to find such splendid examples as those of the Ishtar Gate still existing, *in situ*, and in such an excellent state of preservation (Fig. 1).

Whether anything of supreme value awaits disinterment at lower levels remains to be seen. Slabs of diorite or other hard stone, like the famous stela of Hammurabi, or the similarly written inscription of Nebuchadrezzar, which is (or was) one of the treasures of the library of the

[1] "The Excavations at Babylon." By R. Koldewey. Translated by Agnes S. Johns. Pp. xix+335. (London: Macmillan and Co., Ltd., 1914.) Price 21s. net.