Insects and Disease.

By Dr. S. M. Das, D.Sc.

(*Lucknow University.*)

FROM the earliest of times insects have had an evil reputation so far as they are an annoyance or direct menace to man, or his flocks and herds or are injurious to his crops. But it is only within the last thirty years that there has sprung into prominence the knowledge that, in another and more insidious manner, they may be the enemy of mankind, that they may be among the most important of the disseminators of disease. In this brief period such knowledge has completely revolutionised our methods of control of such diseases, and has become an important weapon in the fight for the conservation of health.

It is interesting to trace the development of our scientific knowledge of this aspect of disease. Mercurialis (1530–1607), an Italian physician, was one of the earliest to point out the relation between insects and disease when he wrote that flies acted as transmitters of plague which was then raging in Europe. Mercurialis had no conception of the animate nature of contagion, and his statement was little more than a lucky guess. It was left for Kirchir (1658) to definitely attribute the production of disease to living organisms, and there is no doubt that he had seen the larger species of bacteria long before Leeuwenhook's discovery of micro-organisms. It took more than two centuries to accumulate the facts to prove this hypothesis. Nothing remarkable was achieved in the eighteenth century; but in the next century, Nott (1848) was the first to attribute the cause of yellow fever to some form of insect life. Beauperthy (1853) stated more explicitly that yellow fever and some other fevers are transmitted by mosquitoes; and it is Dr. Beauperthy whom we must regard as the father of the doctrine of insect-borne disease. It is, however, after the epoch-making discoveries of Manson (1879) that we enter the modern phase of the study of insects and disease. Manson clearly demonstrated the transmission of *Filaria* (a nematode worm), by *Culex fatigans* (a mosquitoe), though it is now known that a number of species of mosquitoes, both anophiline and culicine, may serve equally well. Indeed, since the series of brilliant discoveries by Manson, in 1879, the present tendency is to veer to the other extreme and regard them all as vested with lethal powers over man and beast. It is a great pleasure to mention here that the malaria problem was solved for the first time in India (Ross, 1897), though the disease is quite common on the Roman Campagna and elsewhere.

The real cause of disease lies in parasitism. A *parasite* really means one that takes what it can from another (the host) regardless of any annoyance or any injury that it may accidentally inflict, but not to gratify any imperative predatory instinct. In short, there is benefit of one, the parasite, to the detriment of the other, the host. Parasites are of two main types; those that dwell within the body of the host, called *endoparasites*, and those that settle on the body of the host either temporarily or permanently—the *ectoparasites*. Most of the diseases are caused by endoparasites, while the ectoparasites act as transmitters of the disease from one form to another. It is interesting to note that most of the diseases caused by micro-organisms other than animal endoparasites are contagious, while those caused by animal endoparasites are infectious but not contagious.

Insects, that are lethal or pathogenic to man and other vertebrates, are generally ectoparasitic. Because of their peculiar mode of life they are responsible for the transmission of disease in man and other animals. Thus, biting lice (Mallophaga) attack birds, the sucking lice (Pediculidæ) infest mammals and the flea (Siphonaptera) too attacks mammals. But the group of insects that is the most pathogenic ectoparasite of all, and is responsible for the transmission of most of the terrible diseases, is the Diptera. Flies and mosquitoes are the chief amongst these. It must be kept in mind, however, that the real producers of disease are mostly the small micro-organisms that are the endoparasites of the host; and the ectoparasitic insects are related to the disease inasmuch as they only cause the endoparasites to spread from one host to another. Malaria is neither caused by stale gas nor by the bite of the *Anopheles* mosquito, but it is caused by a protozon called *Plasmodium*. Nor can cholera or dysentery arise from the presence of the house-fly, if the bacteria concerned were absent. The much feared Tse-Tse fly would be and is absolutely harmless—except for a little vexation on the part of the host—in the absence of another protozoon endoparasite in vertebrates called *Trypanosoma*.

On the other hand, many insects do cause disease directly in man and other vertebrates. The gad-flies inflict fatal injury to horses and cattle, the maggots of a bot-fly grow in the frontal sinuses of sheep causing vertigo or even death; and another bot-fly maggot develops in the stomach of horse, enfeebling the animal very much. Myiasis is the name given to the disease caused by these dipterous maggots. Man is also subject to the attack of some of these maggots, and if the patient is left untreated maggots may enter the brain causing the death of the host.

We can, therefore, study insects in relation to disease in two different classes. The species, that, whatever else they may do, exert some direct effect upon the tissues of man; and the species that, whatever other direct effect they may produce, affect the organism indirectly, by introducing other germs or endoparasites. These two classes may be called the '*Insect parasites*' and the '*Insect carriers*' respectively.

The most important disease caused by insect parasites directly is Myiasis. Myiasis in man can be caused in one of five different ways. (1) The larva sucks blood through punctures in the skin: the only example known of this is the 'Congo floor-maggot' (*Auchmeromyia luteola*) which is found in crevices in the floor of huts. The maggot does not cause serious disease though sores may sometimes result. (2) The eggs are deposited in the natural cavities of the body: the screw-worm

fly (*Chrysomyia macellaria*) is the form which is mostly lethal. The adult fly deposits eggs in the nose, ears, etc. of persons sleeping in open air, specially if offensive discharges are present. The larvæ then burrow into the tissues, devouring the mucous membrane and underlying tissues, including muscles, cartilages, peritoneum and even bones, producing terrible sores thereby. If the patient is left untreated the maggots may penetrate the brain and cause death. The larvæ of *Fannia canicularis* often attack the urinary tracts in dirty people in this manner. (3) Eggs are deposited in neglected wounds: a good example of this in India is *Sarcophaga*, the larvæ of which burrow beneath the wound and migrate into the surrounding tissues causing extensive and terrible sores. (4) There are larvæ that live in the subcutaneous tissues causing tumours and ulcers in the body of the host: an example of this is the 'tumbu-fly disease' which is caused by the tumbu-fly (*Cordylobia anthropophaga*). The eggs are laid on the floor of huts and the larvæ enter the skin of the person sleeping on the ground, causing a painful boil-like local swelling. On the other hand, *Hypoderma* larvæ migrate from one spot to another and an ulcer on the arm may disappear one day only to reappear say on the chest next morning. (5) Lastly, some larvæ pass through the alimentary canal of the host and cause what is known as intestinal myiasis. Their presence in the stomach causes nausea, vertigo and violent fits; if in the intestines, the man may suffer from diarrhœa, abdominal pains and hæmorrhage. The larva of the fly *Fannia* may be ingested with decaying fruit where it lays its eggs. The larvæ of the bot-fly (*Gastrophilus equi*) are quite common in horses.

But, by far the most common way in which insects cause disease in man is by carrying the disease from an infected person to an uninfected one. Insect *carriers* may be (1) accidental or casual carriers, (2) the qualified or *adapted carriers* and (3) the *porters* that are intermediate between casual and adapted carriers.

Amongst the accidental carriers the foremost are the non-bloodsucking flies like the house-fly, which may spread abroad mechanically any pathogenic organism of any particular species. But any omnivorous domestic insect (cockroaches, ants, etc.) may serve as carriers of this kind. The ways in which the house-fly transmits disease are so well-known that flies and disease have become almost synonymous. The vomit-spots and fœcal-spots of flies form the most effective sources of fresh infection. A single regurgitation (vomit) means the deposition of thousands of micro-parasites; while in passing through the intestines, the micro-organisms may multiply and be deposited in far greater numbers with the fœcal matter than originally acquired by the fly through the mouth. The commonest flies found round about houses in India are *Musca domestica*, *Musca nebulo* and *Musca ententia*, as also *Calliphora erythrocephla*. Some of the diseases carried by flies are by far the most dangerous and widespread epidemics of all. Typhoid or enteric, dysentery, paratyphoid, summer diarrhœa, cholera, tuberculosis, anthrax, diphtheria, ophthalmia, infantile paralysis, small pox, tropical sore, yaws are all known to spread through flies.

The qualified or adapted carriers are insects that act as intermediate hosts of some micro-parasite, the life-history of which cannot be completed without the intervention of the insect; and since a part of the life-cycle of the micro-parasite is passed in the insect the presence of the insect is essential for the continuance of the disease. Malaria is by far the most important and widespread of the diseases caused in this manner. The role of the mosquito as the intermediate host of the malaria organism was discovered by Manson and Ross and has been confirmed by many medical men. But it should be remembered that it is only a single genus of mosquito (*Anopheles*) that transmits malaria, and, besides, only the females of the species that act as carriers, the males possessing no piercing mouth parts to puncture the skin and suck blood. Again, the bite of an *Anopheles* is not necessarily injurious, unless the insect has had previous access to malaria patients. *Anopheles* may be present where there is no malaria, but it has been found impossible to prove that malaria exists where there is no *Anopheles*.

Some of the other important diseases caused by adapted carriers are Yellow fever, Verruga, Sleeping-sickness, Filariasis, Typhus, Relapsing fever and Trench fever. At one time Yellow fever was a much dreaded scourge, specially in America; but it is now within human control. The history of the campaign against Yellow fever forms a classic example of the control of a serious disease by breaking the continuity of the life-cycle of the causative micro-parasite, by preventing the adapted carrier from transmitting the disease. The experiments that determined the mosquito-transmission theory definitely, are instructive as well as interesting. In a building, mosquito-proof but ill-ventilated, with bedding and clothes of Yellow fever patients, volunteers slept for many nights together, but their health remained unimpaired. Then a room was partitioned by netting, one part of which had infected mosquitoes and the other none. Two men were made to sleep in the two chambers, with the result that the one with the mosquitoes got the fever while the other did not. But directly the latter was transferred to the other chamber, he acquired the disease. Here, again, the mosquitoes concerned are confined to a single genus, *Stegomyia*, which is known as the 'house mosquito' on account of its domestic habits.

Verruga or Phlebotomas fever is transmitted by the *Phlebotomas* fly, though sometimes ticks may also be held responsible for its transmission. Trypanosomyiasis or Sleeping-sickness is one of the most dreaded diseases of central Africa, killing 50,000 natives every year. It is extremely fatal, mortality being placed at a 100%. The causative organism is a *Trypanosome* (Protozoon) which is transmitted by *Glossina palpalis*—the much dreaded Tse-Tse fly. Filariasis is caused by a Nematode, *Filaria* (*Wuchereria*) *bancrofti*, the larvæ of which swarm in large numbers at night in the peripheral circulation of the patient from where they are taken into the alimentary canal of a blood-sucking mosquito—*Culex quinquifasciatus*. These micro-filariæ develop, grow, and penetrating the tissues of the animal, pass to the base of the proboscis of the mosquito whence they are injected into a fresh host. The micro-filariæ are often harmless, but the adults—3 to 4 inches long and thread-like—block the lymphatic canals and cause enormous swellings of feet,

legs, arms and other parts of the human body—causing what is known as Elephantisis. A mosquito, which is quite harmless so far as Malaria is concerned, is therefore, instrumental in the transmission of Elephantisis.

Another terrible disease spread by insect-carriers is Typhus, which, on account of the carrier being human lice, appears in epidemic form during war. In fact it has been observed that war and Typhus go hand in hand. Serbia had a scourge of this disease in 1914, when, at one time there were over 9,000 deaths per day. The causative organism, probably a spirochæte, is taken up from patients and inoculated into healthy men. Monkeys, which were kept free from lice, remained healthy but contracted the disease after access had been given to body-lice from Typhus patients. It is remarkable that the infection is trnsmitted through the eggs to the next generation of lice, so that the progeny of infected lice are already infected without feeding on the blood of Typhus patients. Control of this disease is quite easy, since eradication of lousiness brings freedom from Typhus.

Finally, there are insects, the Porters, which give definite assistance in distributing a specific micro-parasite, but are not essential to its existence. The classic example of this type of insect is the flea, which transmits plague, a disease primarily affecting rats. An epidemic in rats always precedes an epidemic in man. The flea imbibes the specific plague bacillus from an infected rat and the bacillus multiplies in the mid-intestine of the insect, retaining the virulence for a week or more. The bacilli pass out in the excreta of the flea, which is freely expelled during the act of sucking of blood, and thus infect the wound inflicted by the insect on its new host—man. There is no definite adaptation of the bacillus to the flea or *vice versa*, and the bacillus may be disseminated in other ways. The common Indian plague-flea is *Xenopsylla cheopis*. Dengue and Kala-azar are two other Indian diseases transmitted by insect porters. The causative organism of Dengue is carried from man to man by the mosquitoes *Culex fatigans* and *Stegomyia*. Since these mosquitoes are usually present in large numbers the disease often appears in the form of widespread epidemics, though not always fatal. Kala-azar on the other hand is infectious and at the same time very fatal. Thousands of cases occur year after year in the province of Bengal alone. The disease is caused by *Leishmania donovani* (a protozoon) which is transmitted by the common Indian bed-bug (*Cimex rotundus*), the protozoon being found in all stages of development in the bed-bug.

We find, therefore, that over twenty-six of the common diseases, including the most widespread and fatal types, are transmitted by insects. The mortality figures due to these insects are appalling. In India, the mean annual death-roll, for the period 1920–29, due to the flea alone, is over 138,000 ; while the house-fly can claim a death-roll of 800,000 during the same period. The Anopheles mosquito is justly famed for its ravages in India, where more than 1,000,000 men succumb to malaria every year. The bed-bug, transmitting Kala-azar, has actually depopulated whole tracts in Assam and Bengal. It is common sense that a campaign against the causative infect species would surely eradicate most of the maladies that infest man in this most terrible manner. Much has been done in the West towards the eradication of disease-transmitting insects, but very little has been achieved in India, despite the sincere efforts of the Public Health Departments. Certain Indian towns have taken up the cue from the West and established noise-free zones ; how much better for the public it would be, if they established fly-free and mosquito-free zones instead. Cleanliness is the best and surest control for flies. As regards mosquitoes, they can be controlled to a great extent by adopting a few simple measures and strictly observing them. Larvæ should be destroyed by avoiding accumulation of water, using kerosene films on water where the source of water-supply cannot be stopped, and by rearing larvæ-eating fish in tanks and ponds. Recent researches have shown that the tadpoles of the Indian bull-frog are also effective destroyers of mosquito-larvæ.

Though the importance of insects in the dissemination of disease cannot be overestimated, it must be held clearly in view that any harm done to man by them springs up only secondarily, their primary business being the acquisition of food from us. The house-fly and blow-fly all over the world live in and around human dwellings, and may in certain circumstances be harmless to man. Such doubtful messmates as a blow-fly or blue-bottle may perhaps treat a living man as if he were dead. It may casually lay eggs in the nostrils of helpless or incompetent human beings, quite like a parasite. Here we see how an almost innocent commensalism may pave the way for parasitism. Again, an insect that can support life on sweet plant juices may take to sucking the blood of animals. This is the case with mosquitoes. The female Culicidæ (*Culex*) are a good example, for when they do not find blood they take to their original food,—plant juices. Bugs, again, are generally predacious, but bed-bugs have adapted themselves as specific parasites. Finally, there are parasites like lice which are associated with animals of a certain kind (mammals). Here the whole organisation is profoundly modified in the way of adaptation to the particular mode of life they lead. Wings are absent, legs are converted into grapnels for clinging to hair and the mouth parts form a suctorial tube which can be firmly enclosed in the host's skin. Even the eggs are firmly attached to the host's hair ; and the young louse, when it leaves the egg is a finished parasite like its parents.

Insects, therefore, should hardly be blamed for the maladies they cause in man, since the root-cause lies in the specific endoparasitic lethal micro-organisms which insects transmit quite unintentionally. We, however, do not desire to sit in judgment and give a verdict of 'guilty or not guilty'. Our first consideration is the welfare of mankind, and from this point of view Insects are intolerable creatures. They are the most dangerous of man's enemies, veritable wolves in sheep's clothing. 'Our descendants of another century will stand in amazement at our blind toleration of such a menace to life and happiness.'