MEDICAL ENTOMOLOGY

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"Enough to think that Truth can be; come
sit we where the roses blow,
Indeed he knows not how to know who
knows not also how to 'unknow'"

RICHARD BURTON, *The Kasidah.*

PREFACE

Probably no phase of animal biology has shown a more remarkable development during the past forty years than Medical Entomology—the study of insects (including other Arthropods as the *Acarina* and *Crustacea*) which may play a part in the transmission, causation, and spread of human and animal diseases. Even though great progress has taken place since the remarkable discoveries of Fedschenko (1869), Manson (1878-79), Smith and Kilborne (1893), Bruce (1894), culminating in Ross's epochal discovery of 1898 (the date of the beginning of intensive work on insects as transmitters of disease), yet it would seem that the study of insects as disseminators of the diseases of man, animals, and plants is only in its infancy. No attempt is made in the following pages to treat any phase of these biological problems except the relationship of Arthropods to human disease. A short historical chapter is offered the reader and there he will find a brief statement of the beginnings. Should he read further he will see the complexity of the problems involved in the study of a disease that is transmitted by an Arthropod. So involved have some of these problems (as the typhus fever group) become that the ingenuity of the investigator is taxed to the utmost.

This introductory text is offered to the Physician, the Entomologist, the Public Health Worker, the Student, and the Layman in order that it may inform and arouse a keener interest in the problems involved with insect-borne diseases. Though every effort has been made to bring together, in as brief and as accurate a form as possible, all the known human diseases transmitted or caused by insects, it should be stated frankly that in many cases, if not all, our information is incomplete, often fragmentary, and far from what could be desired. The author has not attempted to usurp the function of the physician so that the reader need not expect to find a discussion of treatment; he will find, wherever satisfactory information is at hand, a brief account of the best known methods of controlling the insects involved in disease transmission or causation. Here, again, we find ourselves woefully lacking in developing exact and practical methods of insect control. May we not hope that the present or future generations will provide the necessary funds for the prosecution of such work which means so much to great populations, often entire nations.

The literature on insect-borne diseases has become very extensive, widely scattered in many and varied journals, monographs, government publications, and other sources, and it is extremely difficult to keep abreast of the times. At the end of the first chapter will be found a rather comprehensive list of textbooks, journals, and other publications which will enable the student to gain access to this rapidly growing field of research. Furthermore, each chapter is provided with a selected bibliography and the author has tried to indicate the exact references bearing on the statements made in the text. Many of these references contain extensive bibliographies and such are indicated by starring them.

The writer gratefully acknowledges his indebtedness to the numerous authors whose publications he has consulted. To the authors and publishers who have so generously given their permission for the reproduction of illustrative material he desires to express his sincere thanks. In every case full acknowledgment is given the author and publisher under the illustration; if, by accident, such does not appear, the author makes due apology for the omission. To the numerous colleagues, friends, and students who have aided by suggestions, furnishing material, and in other ways co-operated with the author he desires to tender his sincere thanks. The author desires, furthermore, to express his special obligation to Dr. Charles F. Craig, Colonel, U. S. Army (retired), Professor of Tropical Medicine, Tulane University Medical School, and Dr. Ernest C. Faust, Professor of Parasitology in the same institution, for their kindness in reading portions of the manuscript and making many and valuable suggestions; and also to my former student, Dr. E. Harold Hinman, now at Tulane Medical School, who has carefully checked many parts of the manuscript and aided in many other ways, the author expresses his deep sense of gratitude.

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ROBERT MATHESON

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Chapter I

ARTHROPODS AND HUMAN DISEASE

The phylum Arthropoda plays a rôle in human welfare that is little understood by the great majority of people. In the sea the dominant animal life is not the larger fishes, mammals, etc., but those tiny animals that constitute the greater part of the *plankton*—the free-swimming minute Crustacea on which the others rely for food. Here as free-living vegetarians and scavengers they people the sea in vast numbers and perform their duties with admirable fitness, keeping great bodies of water cleaned of the dead and dying. On the land, insects play a similar but more dominant rôle. For sheer vastness of numbers and incomparable adaptations for meeting the vicissitudes of life they far outrank any other animal or plant association. Who can count the ants that populate our fields and hillsides or the plant lice that suck their nourishment from our wild and cultivated plants? The part insects play in agriculture and commerce has been admirably portrayed by a number of writers, and, at times, over-emphasized, especially in the vast losses agriculture suffers at their hands. It is not our purpose to enter such a discussion here, but the reader will find references at the end of this chapter which may satisfy his craving, even for the sensational. Sufficient for our purposes is the self-evident fact that Arthropods, and especially the order Hexapoda (insects), affect human welfare at every point, and at times endanger his very existence or hold in check his advances in the development of some of the most fertile regions of the globe.

No more striking and dramatic story could be told than the remarkable interrelations that arthropods play in the spread and maintenance of plant, animal, and human diseases. Insects, long regarded and still regarded as unworthy of serious study and consideration by many of our scientists, have gradually forced peoples and governments to devote some of their resources to studies too long delayed. Medical Entomology, a child of recent birth, so young that its voice can scarce be heard above the other scientific babels, is growing into a lusty youth and forcing even the great professions to give it some recognition. Here only a bare outline of its development can be offered and a tribute paid to those great medical leaders and others who have laid down their lives in the investigations of insect-borne diseases.

There are numerous early references to insects as distributors of disease—long before the parasitic origin of disease was established. To Mercurialis (1530-1607), an Italian physician, is usually attributed the first concrete observation that flies serve, in some unknown manner, to spread disease. During the plague (Black Death), which ravaged Europe in his day, he observed that flies may spread the disease by feeding on the internal secretions of the dead and dying and then pass on the disease through their feces which they deposit on the food of the well. França states that Souza (1587) suspected flies of spreading yaws (Framboesia); Bancroft (1769) propounded a similar theory from his observations in Guiana (South America); and many years later Castellani (1907) demonstrated that flies do play a part in the dissemination of this disease—obtaining the organism (*Treponema pertenue*) from the sores and passing it on to the well.

It was not till many years later that well-defined theories of insect propagation of disease were promulgated. Such are those of Beauperthuy (1854) and Nott (1848) relative to the carriage of yellow fever by mosquitoes. Beauperthuy thought that mosquitoes brought the disease from decomposing matter and injected it into man and this was long before the discovery of pathogenic bacteria by Pasteur. At this period there was a remarkable development among German doctors and scientists in the study of helminths. Herbst in 1850 began the work of experimental parasitology when he fed trichinised meat to dogs and obtained the adult worms in his animals; Kückenmeister in 1852 discovered, by feeding experiments, that the "bladder-worms" in rabbits were but a stage in the life-cycle of tapeworms; in 1854 he also showed that "bladder-worms" in pigs were but a stage in the life-cycle of human tapeworms; Virchow and Leuckart in the same decade determined the life-cycle of *Trichinella* (*Trichina*) and Leuckart (1862) solved the mystery of hydatid cysts. All these and other experimental activities undoubtedly fired the minds and guided the thinking of the rising generation.

Filariasis.—In 1863 Demarquay discovered a larval nematode in cases of chyluria; they were later seen by Wücherer in other cases and Lewis (1872) discovered that the blood of man is the normal habitat of this filarial worm (*Filaria sanguinis hominis* of Lewis). About this time (1866) Dr. Patrick Manson, a young medical man of imagination and unbounded energy, left the shores of his native country (England) and took up heroic work first at Formosa and later (1871) at Amoy, China. Here he investigated anything and everything that came his way, developing a remarkable ingenuity for interpreting old and solving new problems. He found filaria abundant in the blood of his Chinese patients, established the "periodicity" of their appearance in the peripheral circulation and in 1879 published the first account of an insect, *Culex fatigans* (the house mosquito of the tropics), serving as the intermediate host in the developmental cycle of any parasite. Though Manson traced the developmental cycle from the intestine through the thoracic muscles, he did not determine how the parasites reached a new host. He believed at that time, like all others, that the life of the mosquito was short, the females dying after laying their eggs, and so he formulated the theory that man was infected by drinking the water in which infected mosquitoes died. It was not till 1900 that the true method was discovered by Low. This discovery served as the real starting point of medical entomology. In 1890 Manson returned to London, engaged in the practice of medicine, and urged the development of tropical medicine. In 1893 he evolved his mosquito theory of malaria. Though he never had an opportunity to test his theory, yet he so impressed his ideas on Dr. Ronald Ross that the latter eventually made his epoch-making discovery in 1897-98.

Here only one other contribution by Manson can be recorded. *Loa loa,* the African eye worm, was long identified both in America and Africa, but nothing was known of its life-cycle. In 1891 Manson reported a new filaria in the blood of natives from the Congo and Old Malabar, naming it *Filaria sanguinis hominis major* (later known as *Microfilaria diurna*). On account of its diurnal periodicity Manson predicted that some blood-sucking, day-feeding fly would be found to be the intermediate host. From talks with the natives of Old Calabar he suggested that the "mangrove flies," *Chrysops dimidiata* and *Chrysops* spp., would prove the correct flies. In 1912 Leiper confirmed this prediction and Kleine (1915) worked out the methods of transmission in detail.

Another remarkable discovery should be recorded here; in fact, it antedated Manson's work. Fedschenko (1869) demonstrated that

Cyclops spp. (Crustacea) were the intermediate hosts of the famous "fiery serpent" of Moses, the dragon worm, *Dracunculus medinensis* Linn. (hence the name of the disease, dracontiasis). Manson (1894) confirmed and extended the work of Fedschenko.

Malaria.—In 1880, Laveran, working in Algeria, discovered the parasite of malaria in the red blood cells of his patients. It required more than ten years before Laveran's organism was accepted as the causal agent of the disease. Though during this time much had been learned about the parasite, little progress was made till Manson evolved his mosquito theory and impressed it on Ronald Ross, a young British surgeon working in India. So far-fetched appeared Manson's theory that he was dubbed "Mosquito Manson" by his distinguished medical confrères and regarded as rather fit for a lunatic asylum. Curiously enough, an American physician, A. F. A. King, had, in 1883, also propounded a mosquito-malarial theory which, unfortunately fell on deaf ears and unimaginative minds. Under Manson's urging Ross continued to work and in 1897 recorded his great discovery that "dappled-winged" mosquitoes served as the definitive hosts of species of *Plasmodium.* Ross's work was done under the most trying conditions and at a time when no one knew mosquitoes and less about their biology. His results were fully confirmed by Bastianelli, Bignami, and Grassi (1898 and 1899), Manson (1898), and Sambon and Low (1900). This discovery by Ross is undoubtedly one of the great landmarks in medical history for it has led to the reduction, and can lead to the elimination, of the most widespread and devastating of human diseases.

Piroplasmosis.—While the mosquito-malaria theory came to fruition in India and Europe, Theobald Smith, working in Texas, discovered the causative agent of Texas or Red-water Fever of cattle, *Piroplasma bigemina,* a red blood cell inhabiting protozoan. In 1893 Smith and Kilbourne published the results of their work. They demonstrated that the cattle tick, *Boophilus annulatus* Say, was the intermediate host. In addition they showed that the parasite passes from the adult female ticks to their offspring and only young ticks (larvæ) infect new hosts. This is the first instance of a protozoan passing by way of the egg to infect the young which, in turn, transmit the disease to new hosts. Many other discoveries in the field of protozoan parasites of domestic animals have since been made and are of the greatest importance to animal husbandry. It would take us too far afield to discuss them here.

Trypanosomiasis.—From about 1893 to the present time the most remarkable discoveries have been made in the field of insect-borne diseases. These can be reviewed only briefly. In 1895 Bruce discovered *Trypanosoma brucei,* the causative agent of Nagana or Tsetse-Fly disease of cattle in Zululand and demonstrated that the Tsetse-Fly, *Glossina morsitans* Westw., could transmit the disease from the sick to the well. It was not, however, till 1909 that Kleine proved the developmental cycle in the fly and showed the true method of transmission. In 1901, Forde, in West Africa, observed a parasite in the blood of a European patient suffering from Gambian sleeping sickness; later Dutton (1902) recognized it as a trypanosome and described it as *Trypanosoma gambiense* Dutton; Castellani (1903) and Bruce and Nabarro (1903) proved this trypanosome was the causative agent of sleeping sickness and that *Glossina palpalis* R.-D. was the transmitting fly. In 1910 Stephens and Fantham described *Trypanosoma rhodesiense* as the etiological agent of Rhodesian sleeping sickness while Kinghorn and Yorke (1912) proved that *Glossina morsitans* Westw. was the transmitter. In South America, Chagas (1909) demonstrated that a trypanosome, *T. cruzi,* was transmitted by a bug, *Triatoma megista* Burm. This parasite is the etiological agent of South American trypanosomiasis or what has been called Chagas's disease.

Yellow Fever.—While these African investigations were being developed, the American Army Yellow Fever Commission, consisting of Reed, Carroll, Lazear, and Agramonte, made a still more remarkable discovery. They demonstrated (1900) that yellow fever can be transmitted only through the agency of the "tiger mosquito" or yellow fever mosquito (*Stegomyia fasciata, Aedes calopus, Aedes argenteus*—now known as *Aedes aegypti*). Though Carlos Finlay, a Cuban physician, had as early as 1880 propounded a mosquito theory for yellow fever, it must ever redound to the glory of this band of devoted workers that, due to their discovery, one of the most deadly of human diseases could now be controlled or even eliminated. Unfortunately the causal organism was not discovered and has not up to the present time. Though Noguchi (1919) announced that *Leptospira icteroides* was the etiological agent and his work was accepted by many workers, his results have since been abundantly disproven. For over a quarter of a century it was firmly believed that the only transmitter of yellow fever was the "tiger mosquito" and man the only animal susceptible to the disease. On this belief prophylactic measures against yellow fever were based and remarkable results were obtained in reducing and controlling outbreaks of the disease. However in 1928 two most important contributions were made to the yellow fever problem. Stokes and his associates, working in West Africa, demonstrated that monkeys, *Macacus rhesus,* were susceptible to the disease and since then some eighteen species of monkeys, both from the Old World and the New World, have been shown susceptible to yellow fever. In the same year, Bauer, working in the same laboratory, proved that three other species of mosquitoes were capable of transmitting yellow fever. Since that date some seven additional species of mosquitoes have been shown capable of transmitting yellow fever. These results have not only thrown new light on the yellow fever problem but should modify to some extent the current methods of prophylaxis.

Plague.—In 1894, Yersin and Kitasato independently discovered the causative agent, *Bacillus pestis,* of plague, and Yersin demonstrated that the disease in man was identical with a plague-like disease of rodents. Simond (1898) suggested that fleas were agents in the dissemination of plague and his experiments showed that he was on the right track. In 1903-04, Verjbitski demonstrated that fleas act as vectors of the plague bacillus but his results were not published till 1908. The development of the plague bacillus in the gut of the rat flea was independently discovered by Liston (1905) and the rôle fleas play in the epidemiology of plague fully determined by the British Plague Commission (1907-08). Finally Bacot and Martin (1914) demonstrated the method of transmission of the plague bacilli by fleas.

Dengue.—Dengue or breakbone fever, a disease of unknown etiology, was shown by Graham (1902) to be mosquito-borne and his results were confirmed by Ashburn and Craig (1907). Though the mosquitoes with which these investigators were supposed to have worked have since been shown not to be true vectors, yet their discovery was of great importance. The true vectors have since been shown to be *Aedes aegypti* and *Aedes albopictus.*

Pappataci Fever (three-day fever or sandfly fever), another disease of unknown etiology, was shown by Doerr, Franz, and Taussig (1909) to be transmitted by a sandfly, *Phlebotomus papatasii* (*Psychodidae*).