SCIENCE

VOL. LX — DECEMBER 19, 1924 — NO. 1564

CONTENTS

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

Entered as second-class matter July 18, 1923, at the Post Office at Lancaster, Pa., under the Act of March 3, 1879.

MEDICAL ZOOLOGY AND HUMAN WELFARE[1]

EVERY one is more or less familiar with the relation of medical zoology to human welfare, but many of us do not realize what a very great influence both the scientific and practical phases of this subject have had upon our daily lives and upon the progress of the human race. Medical zoology is the subdivision of the great science of zoology which deals with groups of animals selected on the basis of their intimate association with man. Certain of these animals, such as scorpions and snakes, are of medical importance because of their venomous bites; others, such as certain game animals of Africa that harbor the germs of sleeping sickness, act as reservoirs from which transmitting agents obtain their infections; and some animals carry as external parasites the transmitting agents themselves, such as the rat which is infested with plague fleas. Zoologically the principal group with which medical zoologists are concerned are the parasitic protozoa, parasitic worms and the insects that may transfer these organisms as well as bacteria and filterable viruses from an infected to an uninfected animal. Since most of these organisms are parasites the terms medical zoology and parasitology are often used synonymously.

Medical zoologists do not limit themselves to the study of those parasites or insects that have been proved to be directly concerned in human diseases but investigate also the parasites of lower animals and plants, since these are usually more easily obtained for experimental work and often belong to the same genera as do the human parasites; hence the results of their study can be translated more or less directly into terms of human parasitism. It may be worth while at this point to define a parasite and separate parasites into their several categories. A parasitic animal is one that lives on or in and at the expense of another animal or plant; the latter is called the host. In many cases animals or plants are closely associated together, one partner benefiting by the association, whereas the other is neither injured nor benefited. This condition is known as commensalism. Again, two closely associated organisms may be mutually beneficial and sometimes one is unable to live without the other. This type of partnership is known as symbiosis. In a third cate-

[1] A lecture delivered at Mt. Holyoke College on November 14, and at Mount Union College on November 19, 1924.

gory belong the true parasites which always injure their host. Some of these are ectoparasites; they live on the outside of the body, and are, to a certain extent, independent of their hosts; among these are insects such as bedbugs, lice and fleas. Others, called entoparasites, succeed in entering the body, where they usually become located in a particular organ or tissue; for example, the dysentery amoeba lives in the intestine, the malarial parasites in the red blood corpuscles and the trichina worms in muscle. The lives of many of these parasites are not particularly happy, since their life-histories are often extremely complex and the conditions that they must contend with in order to maintain themselves and continue their race are such as to make our own mode of existence seem ridiculously simple. Allow me to give several examples.

The commonest liver fluke of man is *Clonorchis sinensis,* a species that occurs in the bile ducts in inhabitants of Japan, China, Korea, Formosa and Cochin China. The true host of this species is man or some flesh-eating animal such as the cat or dog; but before any of these final hosts can be infected the young must pass through two types of intermediate hosts. The eggs of the fluke are laid in the bile ducts of the liver down which they pass into the intestine and thence to the outside. If these eggs chance to find their way into a body of water they soon hatch into free-swimming ciliated larvae called miracidia. No further development takes place unless the miracidia are fortunate enough to encounter a snail of a certain species. When this occurs they energetically burrow their way into the tender body of the snail and grow rapidly at the expense of its soft tissues. Then a period of reproduction ensues, resulting in enormous families of young flukes called cercariae. These cercariae, however, are not yet fashioned in the image of their parents, but must first escape from their birthplace and find certain species of fish in which to spend their adolescent period. After their strenuous efforts to find one of these fish and after burrowing into its tissues they settle down to rest a while and hence form cysts. This resting period may last for a long time, but if infected fish, that is insufficiently cooked, is eaten by man the larval flukes break out of the cysts and many of them migrate into the bile ducts. Here in the bile ducts the larval flukes grow rapidly into vigorous adults and within a month are busily engaged in laying eggs so that the race may not die out. It required the labor of many scientists working over a period of many years to determine all these details, and it must have been very exciting to unravel the tangled threads of this life-cycle, since no one could possibly imagine such a wonderful series of events as these lowly worms live through before they are ready for parenthood. How many of the eggs that are laid reach water; how many of the miracidia that hatch from these eggs succeed in finding the right kind of snail; how many of the cercariae reach the appropriate fish in which to encyst; and how many of these fish are eaten raw by human beings no one knows; but it must certainly be a very small percentage of the original number. Fortunately for the parasite extraordinary powers of reproduction seem to have evolved with the parasitic habit, and enormous numbers of eggs are laid and cercariae developed. At any rate the persistence of the race proves that enough eggs are laid to prevent this lowly worm from becoming extinct amid the complexities of modern life. Well might the successful parent be proud to have overcome the many vicissitudes that beset her path at every turn, and I am sure you will agree with me that our lives seem humdrum indeed compared with that of *Clonorchis sinensis.*

The life-cycle of the malarial organism is equally wonderful, although not complicated by the intervention of *two* intermediate hosts. The malarial sporozoite that is inoculated into the blood of man by the bite of an infected mosquito must successfully avoid the white corpuscles that are always at hand to devour it, and must find a red blood corpuscle into which it can bore its way. Here it is sheltered during its growth period. Finally, however, it divides into a dozen or more daughter merozoites which break out of the blood corpuscle and must in their turn escape the white corpuscles and penetrate fresh red corpuscles. Some of those that succeed develop into sexual forms known as gametocytes. The gametocytes, however, can not continue their development in the blood of man, but perish unless they are sucked up into the stomach of certain species of mosquitoes. If they are so unfortunate as to be engorged by a culex mosquito they are promptly digested, but if the right sort of anopheline mosquito swallows them they are stimulated to further activity; eggs and spermatozoa are formed; fertilization takes place; and a worm-like creature evolves that penetrates the wall of the mosquito's stomach, where a cyst is formed. In this cyst enormous numbers of new sporozoites are produced. These in time break out into the body cavity of the mosquito, and some of them succeed in getting into its salivary glands. Here they finally perish unless their particular mosquito bites a susceptible person and they are fortunate enough to pass out into the blood stream of the new host. Any particular malarial organism obviously has small chance of fulfilling his mission in this world, but so great are the powers of reproduction of these parasites that only one in millions needs to complete its life-cycle in order to maintain the race successfully.

The facts about *Clonorchis sinensis* and the malarial organism are well known and are accepted by most of us without realizing what a tremendous amount of labor and devotion were required to bring them to light. The history of our knowledge of malaria is of great interest not only *per se* but also as an example of how great discoveries are often brought about by the researches of hosts of first-class investigators covering a period of many years. The disease we know as malaria was recognized long before the causative agent was determined and many opinions were expressed regarding its etiology. It was by various early authorities thought to be due to meteorological conditions or to the effects of changes of temperature on the nervous system or to contaminated drinking water or to be communicated by personal contact, but it was by most people considered to be due to bad air, and many people believe even to-day that damp air is responsible for the disease. These suggestions seem rather ludicrous in the present state of our knowledge of malaria but were seriously discussed at the time they were proposed. Later, various microscopic organisms were announced as the causative agents, including unicellular algae, fungi and bacteria. In the meantime knowledge of animal parasites was increasing; flagellate protozoa (trypanosomes) were discovered in the blood serum of fishes by Valentin in 1841 and sporozoa (haemogregarines) were noted *inside* of blood corpuscles by Bütschli in 1876. So many organisms had been accused of causing malaria that when the true parasite was discovered by Laveran in 1880 its importance was not at first recognized. At this time the attention of scientists was directed toward the so-called Bacillus malariae which Klebs and Tommasi-Crudeli in 1879 claimed to have determined by experimental tests to be the causative organism, and it was not until 1885 that Laveran's findings were generally accepted. The true parasites of malaria were then found in various countries and it was not long before three species were recognized, each responsible for one type of malaria; *Plasmodium vivax* for tertian malaria, *Plasmodium falciparum* for aestivo-autumnal malaria, and *Plasmodium malariae* for quartan malaria. Life-history studies were carried on in many laboratories, but one stage escaped detection for many years and that was the most important part of the life-history, namely, the stage during which the organism is transferred from one human being to another. It was realized, however, that the missing link could easily be supplied if the method of transmission were known; hence for almost two decades some of the best scientific minds of the world were engaged in attempts to find the key to this puzzle. The fascinating story of the discovery of the method of transmission of malaria has recently been published in detail by Sir Ronald Ross in his "Memoirs" and may be cited as an excellent illustration of what can be done by scientific zeal and perseverance under extremely adverse circumstances. The story is too long to be told here, so all I can do is to state that Ross demonstrated in mosquitoes the missing stages in the life-cycle of bird malaria in 1896 and that subsequently Italian investigators proved that anopheline mosquitoes act as the transmitting agents of human malaria.

These discoveries completed our general knowledge of the life-cycle of the malaria parasites and showed us immediately the point where our attack should be directed in order to control malaria since the causative organism can not be transmitted without the presence of certain species of anopheline mosquitoes. Malaria can be prevented from spreading in any locality (1) by destroying all anopheline mosquitoes, (2) by screening infected persons so that mosquitoes when present can not bite them, (3) by screening uninfected persons so that infected mosquitoes do not have access to them and (4) by treating infected persons with quinine so that they can not transmit the organisms to mosquitoes. All these means have been employed with success in various parts of the world. The methods of controlling malaria are now well known, but each locality presents problems of its own that must be overcome before success is assured. The plan that seems to have gained the greatest confidence among public health men is to make a thorough preliminary study of each type of area it is desired to bring under control and then institute measures on a large scale.

The history of yellow fever is similar in many respects to that of malaria. During the past century yellow fever was one of the most dreaded epidemic diseases in the United States, and it is estimated that more than 500,000 cases occurred in this country from 1793 to 1900. Notable outbreaks took place in Boston in 1691 and 1693, in New York in 1668 and up to 1856, in Philadelphia in 1793 and in Baltimore in 1819. One tenth of the population died in the Philadelphia epidemic of 1793. The effect this had on the inhabitants is described by Mathew Cary as follows:

> The consternation of the people of Philadelphia at this period was carried beyond all bounds. Dismay and affright were visible in the countenance of almost every person. Of those who remained, many shut themselves in their houses and were afraid to walk the streets. . . . The corpses of the most respectable citizens, even those who did not die of the epidemic, were carried to the grave on the shafts of a chair (chaise), the horse

driven by a negro, unattended by friends or relative, and without any sort of ceremony. People hastily shifted their course at the sight of a hearse coming toward them. Many never walked on the footpath, but went into the middle of the streets to avoid being infected by passing by houses wherein people had died. Acquaintances and friends avoided each other in the streets and only signified their regard by a cold nod. The old custom of shaking hands fell into such disuse that many shrunk back with affright at even the offer of the hand. A person with a crepe, or any appearance of mourning was shunned like a viper. And many valued themselves highly on the skill and address with which they got to the windward of every person they met. Indeed, it is not probable that London, at the last stage of the plague, exhibited stronger marks of terror than were to be seen in Philadelphia from the 24th or 25th of August until pretty late in September.

New Orleans was periodically visited by yellow fever; in 1853 there were 7,848 deaths, in 1858, 4,854 deaths and in 1878, 4,046 deaths. The last large outbreak in that city appeared in 1905.

Before the causative agent of yellow fever was discovered by Noguchi in 1919 and its transmitting agent was demonstrated by Reed and his coworkers in 1900, it had been attributed to swamps, tropical temperature, atmospheric conditions, etc. The disease was brought under control because of the discovery of the transmitting agent long before its cause was ascertained. Drs. Reed, Carroll, Agramonte and Lazear were sent to Cuba to study yellow fever in 1900. Already in 1881 Dr. Carlos J. Finley had expressed the theory that yellow fever is propagated by mosquitoes, Dr. Henry R. Carter had made careful observations on the incubation period of the disease, and Ross had proved malaria to be transmitted by these insects. Hence the American investigators were able in a very short time to produce yellow fever experimentally in human volunteers by the bites of mosquitoes and thus to lay the foundation for the epochmaking campaigns carried on by General Gorgas and his colleagues in Havana and the Panama Canal Zone. These two campaigns were among the earliest and best for the control of yellow fever and malaria and illustrate two types of control work, that in Havana in a thickly populated municipality and that in Panama in a thinly populated rural district.

Efforts to eradicate yellow fever from Havana by mosquito reduction were begun in 1901 under the direction of General Gorgas at the same time as were similar efforts for the control of malaria. The average death-rate from yellow fever in Havana during the years 1853 to 1900 was 754. In 1901 the destruction of the mosquito vectors brought this number down to 18 and within a few years the entire island of Cuba was declared free from yellow fever.

Malaria control work was started in Havana in 1901. During the preceding decade (1890–1900) there was an average annual death-rate from malaria of 564 among a population of about 350,000, whereas during the next decade (1900–1910) after mosquito control measures had been inaugurated the average annual death-rate was 44, with a largely increased population. Since then malaria has been practically absent from Havana, a condition that is maintained easily and at low cost.

After his successful campaign in Cuba in 1904 General Gorgas began work as chief sanitary officer of the Panama Canal Zone. Here he found a large area covered with jungles, rivers and swamps, presenting new problems for mosquito control. These, as every one knows, were successfully solved and the canal was built. Wet areas in which mosquitoes were breeding were filled, drained or oiled; poisons were added to ponds and streams to kill mosquito larvae; the natural enemies of the mosquitoes, such as fish and dragon flies, were distributed to bodies of water where mosquitoes were breeding; and houses were screened to protect the employes from the adult mosquitoes. The results were quite gratifying. Malaria and yellow fever prevented the French from building the Panama Canal. Their losses have been estimated at fifty thousand men. Within a few years the sanitary officers of the United States had rendered these diseases a negligible factor in the Canal Zone and now one is as safe from malaria and yellow fever in the Panama Canal Zone as he is in New York City.

It is impossible in the time at my disposal to discuss even briefly all the diseases that the study of medical zoology has succeeded in practically eliminating from the world. It is only possible to cite certain interesting examples.

The Katayama disease of Japan, a disease which is known by scientists as schistosomiasis japonica, has only a local distribution in Japan; its most important endemic center being in the Katayama district near Okayama. This area contains about one hundred square miles of territory and at the height of the disease perhaps thirty thousand of its inhabitants were infected. The history of the discovery of the causative agent and its control indicates how remarkably simple the eradication of a disease may be after the life-history of the parasite causing it is fully known. Katayama disease was first described by Fujii in 1847, but it was not known to be due to the presence of the oriental blood-fluke until 1904, when the worms were found in man by Japanese investigators. During the next three years the effects of the worms on the human body were fully worked out, but the method of infection was still unknown. Contaminated drinking water was thought to be the most probable method, but by an ingenious series of experiments Fujinami and Namakura in 1909 proved that the parasites gained entrance to the body through the skin. Many Japanese investigators were by this time profoundly interested in this problem and by the end of the next four years the entire life-history of the organism had been worked out, especially by Miyairi and Suzuki, a life-history similar in many ways to that of *Clonorchis sinensis.* The eggs that are passed in the feces hatch in the water, giving rise to ciliated miracidia. These swim about until they come in contact with a certain species of snail into which they bore their way. Within the snail they undergo rapid multiplication, finally emerging in a form resembling a minute fork-tailed tadpole. These little organisms then lie in wait for any animal they may chance to come in contact with, whereupon they penetrate the skin, make their way into the blood stream and finally reach the liver, where they grow into adult worms. The solution of the purely zoological problem of the life-history of this worm accomplished for the Katayama disease what the elucidation of the transmission of the malarial organisms by mosquitoes did for malaria—it furnished a means of attacking the intermediate host. This was immediately begun and it was soon discovered that the addition of lime to the water resulted in the death of the snails and without the snails the worms could not complete their life-cycle successfully and were hence destroyed. Between the years 1913 to 1923 the Katayama disease was practically eradicated from its original home by the elimination of the intermediate host, the snail.

The knowledge gained by the study of the oriental blood-fluke by the Japanese immediately enabled other investigators to solve the problems presented by blood-flukes in other parts of the world. All that needed to be done was to determine the species of snail that acted as intermediate host and by destroying these snails prevent the production of the infective stages of the parasite. This method will probably in time bring about the eradication of all human blood-flukes.

Another disease whose conquest may be placed to the credit of medical zoology is bubonic plague. Epidemics of this disease have occurred from time to time in various parts of the world. In the 14th century one fourth of the population of Europe died of plague, and a similar catastrophe might have overtaken the United States when this disease was introduced into San Francisco in 1900 if we had not known how to control it. The plague germ was discovered by Yerson in 1894 and found to be the same as that occurring in rats. In 1905 Liston noted the growth and multiplication of these germs in rat fleas, and in the following year the British Plague Commission in India proved the rat flea to be the principal transmitting agent. Epidemics of plague can now be prevented by destroying rats and rat fleas. This was done by the U. S. Public Health Service in the San Francisco epidemic; over a million rats were caught, examined and destroyed. Unfortunately the ground squirrels in certain parts of California became infected and over twenty million of them were killed also before the disease was considered under control. As a result of these efforts only 187 cases of plague in man occurred in the California epidemic. Within the past month plague has again broken out in California, but our knowledge of the transmission of the disease will undoubtedly make it possible to prevent its spread and thus save the lives of thousands of persons.

Other insects besides the flea that serve as vectors of human diseases are phlebotomus flies that carry three-day fever and are suspected of transmitting Verruga Peruviana and cutaneous leishmaniasis; culicine mosquitoes that carry filariasis as well as yellow fever and dengue; tsetse flies that are the vectors of sleeping sickness; house flies that distribute the germs of typhoid fever and similar diseases; assassin bugs that carry Chagas fever in South America; and lice which have been proved to be vectors of relapsing fever, typhus fever and trench fever. Nearly related to these insects are the ticks which carry relapsing fever and Rocky Mountain spotted fever.

The most recent and in many ways the most remarkable conquest of disease due to parasitic organisms presents an example of a house divided against itself, since one parasite is engaged to combat another parasite. The disease called general paralysis, paresis or softening of the brain has been known and dreaded for centuries. It is the result of infection with the syphilitic organism, *Treponema pallidum,* and is a form of insanity characterized by the gradual loss of the mental faculties, followed by dementia, death taking place usually in from a few months to five or six years. Wagner von Jauregg, of Vienna, discovered in 1920 that malarial organisms, when inoculated into patients suffering from general paralysis, brought about a distinct improvement in the course of this disease. Patients were allowed to go through eight or nine malarial paroxysms; were then treated with quinine to check the malaria; and were finally given six injections of neosalvarsan, which is a specific therapeutic agent for syphilis. Von Jauregg reported 120 completed cases. Of these, 30 were discharged from the hospital as cured and 51 were greatly improved but not entirely cured. What the mechanism of these cures is is not known, but the theory is that malarial immune bodies are produced which activate the protective powers of the body against paresis.

These investigations naturally stimulated similar studies in other parts of the world, the results of which are now appearing in scientific periodicals. Among these is a recent report by Yorke and Macfie, of the Liverpool School of Tropical Medicine. Eighty-four patients suffering from general paralysis were studied by these investigators, and sufficient time has elapsed since their experiments were begun to furnish definite results. The physical and mental condition of 23 of these patients improved so much that they were discharged from the hospitals; great physical and distinct mental improvement was observed in 17 of the patients; a physical gain but no mental progress was noted in 10 cases; and although no noticeable change was evident in 20 of the patients, many of these would have died if they had not been infected with malaria. The fact also should be emphasized that no patient suffering from general paralysis had ever previously been discharged from the hospitals in which Drs. Yorke and Macfie carried on their experiments. Here then is the malarial organism, which causes one of the most important diseases of man, being employed to cure another and even more dreadful parasitic disease.

It is interesting to note the rapid progress that has been made in the control of diseases due to animal parasites throughout the world, and it is gratifying to us to realize that an American institution is the foremost leader in this movement. I refer to the Rockefeller Foundation. This foundation grew out of the discovery by medical zoologists that much of the shiftlessness and misery among certain classes of people in our southern states was due to hookworm disease. The clinical symptoms of hookworm disease, including dirt-eating, laziness and anemia, were described from Louisiana as early as 1821, and fragmentary reports of the finding of the worms themselves were recorded at intervals beginning about 1864; but serious attention was not directed to the disease until Dr. C. W. Stiles, of the Hygienic Laboratory of the United States Public Health Service, began a series of studies which culminated in the organization of the Rockefeller Sanitary Commission in 1909. The control of hookworm disease is a relatively simple matter, but Dr. Stiles and the commission were subjected at first to much ridicule, which, however, gave way to praise as soon as the quick and revolutionary results of their work began to appear. Great progress was made during the four years this commission was in existence. At the end of this time (1913), the Rockefeller Foundation was established, with an initial endowment of $100,000,000, for the purpose of promoting "the well-being of mankind throughout the world," and one of the first acts of this foundation was the reorganization of the Rockefeller Sanitary Commission as the International Health Board. Among the principal objects pursued by this board have been the control of hookworm disease, malaria and yellow fever. Nearly $4,000,000 were spent from 1913 to 1923 for the relief and control of hookworm disease, over $1,000,000 for yellow-fever control and almost $800,000 for malaria control. The indirect results of this work have probably been no less important than the direct decrease in the incidence of these diseases in the areas covered, since permanent public health activities of various sorts, supported entirely by the people concerned, have grown out of these campaigns for the control of diseases due to animal parasites.

Much of this work has been done in tropical and semi-tropical countries largely because diseases due to animal parasites increase in number and variety as one approaches the equator—a condition resulting from a combination of favorable factors. Transmission from one host to another is easier in the tropics than in the north, where the infective stages of the organism are often subjected to freezing temperatures; sanitary conditions are usually less rigid in the tropics, thus facilitating the spread of disease, and the transmitting agents, such as mosquitoes, are active almost continuously throughout the year. In the north many diseases of animal origin have almost entirely disappeared because the breeding places of the transmitting agents have been eliminated by intensive cultivation of the soil; and pollution of the soil is prevented by modern plumbing. Residents of rural districts in the north, where sanitary measures are not as strictly enforced as in the cities, are more frequently infected than those of the cities, but even in the latter there is a surprisingly high incidence of infection with certain animal parasites. For example, Dr. G. C. Payne and I compiled data contained in the literature for about twenty thousand cases which had been examined for intestinal protozoa, and found that 20 per cent. were infected with *Endamoeba coli*, 12 per cent. with *Giardia lamblia*, 9 per cent. with *Endamoeba hystolytica*, 4 per cent. with *Chilomastix mesnili* and 3 per cent. with *Trichomonas hominis*. I have no doubt but that this average would be found to hold among the members of my present audience. Fortunately these organisms are not usually pathogenic.

Facilities for rapid transit have made of public health a world problem. Disease-producing organisms may be transported from one locality to another and for long distances either by human carriers or by the intermediate hosts. A human carrier is a person who is infected and thus carries the parasites from place to place on or within his body but who does not exhibit symptoms of disease. Carriers more or less unconsciously distribute the infective organisms and are responsible for spreading infectious diseases among susceptible persons. The intermediate hosts of animal parasites are usually lower animals, such as cattle, dogs, snails and insects; these are also frequently transported from one country to another. It has not always been necessary, however, to take drastic action for the purpose of preventing the importation of animal parasitic diseases into the United States because of their complicated life-histories. Malaria can not be transmitted in a locality where certain species of anopheline mosquitoes are absent, even if persons with malarial parasites in their blood are present in large numbers. The Katayama disease of Japan can not gain a foothold in this country, even though many infected Japanese are allowed to enter, because the species of snail which acts as the intermediate host of the oriental blood fluke does not exist in the United States. The habits of the general population have a considerable influence on the spread of parasitic diseases. For example, the lung fluke, *Paragonimus westermani,* which is also a common parasite in Japan, depends for its transmission upon the peculiar habit of certain orientals of eating certain fresh water crabs raw in which are the encysted stages of the fluke all ready to start a new infection in any one who swallows them. We in the United States are safe from this parasite because we do not eat raw crabs. We, however, place ourselves in danger whenever we visit foreign countries, particularly in the tropics. One must be careful when in certain parts of China, Japan and Egypt to avoid water for bathing purposes that may contain the infective stage of the blood fluke. It is necessary also to see that all uncooked vegetables are thoroughly cleansed in order to escape ingesting hookworm larvae and cysts of the dysentery amoeba and of intestinal flagellates. More precautions must also be taken to avoid being bitten by mosquitoes that may transmit malaria, yellow fever, dengue and other diseases.

It is evident that one field in which medical zoology has taken the leading rôle is that of rendering the tropics as habitable for man as are the temperate regions of the earth. I have already described the conquest of malaria and yellow fever and shown how Havana, Cuba and the Panama Canal Zone were transformed into healthful districts by putting into operation simple control measures perfected from the results of scientific investigations. All this has a distinct bearing upon one of the greatest problems before mankind at the present time—the problem of population. Statistics show that the world's population has increased about two and one half times during the past century. Population is continuing to grow and millions of acres of new lands must each year be made productive in order to keep mankind from hunger and starvation. Many methods of preventing further increases in population have been suggested and no one can predict what the future may have in store for us in this direction. We must, however, face the problem that confronts us to-day, and this problem involves the opening up of new land every year. In tropical America and in other tropical countries large areas of fertile country exist that are now unproductive. That these tropical regions can be made healthful to men from the colder regions of the earth has been proved again and again by various nations that have founded colonies in the torrid zone. To do this it has only been necessary to control certain diseases, and these diseases have been for the most part due to animal parasites or their transmitting agents.

During the past summer I obtained a first-hand knowledge of conditions in tropical America, having visited plantations and hospitals in Cuba, Jamaica, Guatemala, Honduras, Costa Rica, Panama and Colombia. The number of deaths and extent of the sickness and misery due to diseases of animal parasitic origin was quite startling. In fact the principal difference between the diseases of the American tropics and those of the northern United States is the prevalence in the former of maladies due to infections with animal parasites. Statistics gathered together by the doctors in the nine divisions of the United Fruit Company show that malaria alone was responsible in 1923 for 38 per cent. of 27,654 cases treated in their hospitals, and that 205 of every thousand employees were admitted to their hospitals with malaria and that ten of every thousand deaths were due to this disease. Hookworm disease is more insidious than malaria; it does not bring about sudden prostration but slowly saps the vitality of its victims; hence, although it is probably as widespread, hospital admissions due to its ravages are not so frequent; nevertheless 5 per cent. of the hospital cases were suffering from this disease. A third cause of sickness and death is amoebic dysentery. In 1923, 420 cases of amoebic dysentery were treated in the hospitals of the United Fruit Company, and a large proportion of these patients failed to recover, principally because the disease was in an advanced stage when treatment was begun. Not infrequently natives are encountered in tropical America who are veritable museums of medical zoology. Many of them are chronically infected with from one to three species of malarial parasites, with two or more species of intestinal amoebas, with several species of intestinal flagellates, with hookworms and from two to four other species of worms, and externally with several species of parasitic insects. Undoubtedly the tropics offer a happy hunting ground for medical zoologists as well as for public health workers. Here are vast areas that may be made habitable by the introduction of control measures that have already been perfected and are very simply put into operation.

Before concluding my lecture I should like to say a few words about where work in the field of medical zoology is being done. In the first place, much of the subject known as tropical medicine is devoted to the study of diseases due to animal parasites, hence we find medical zoology the most important subject in schools of tropical medicine such as those at London, Liverpool, Brussels, Amsterdam and Hamburg. In this country investigators in the field of medical zoology are working in the U. S. Public Health Service, the U. S. Department of Agriculture, in various institutions, such as the Rockefeller Institute, and in colleges and universities. Physicians, especially those living in tropical or semi-tropical countries, are also continually adding to our knowledge of animal parasites and human disease.

The successful control of such diseases as malaria, yellow fever, hookworm disease, plague, Katayama disease and many others is very gratifying to medical zoologists, since millions of human beings have thus been saved from suffering and death. But there are still many diseases that are only partly under control and about which very little is known. Even malaria, which has been studied for many years by some of the best of our scientists, still offers many problems for solution. It sometimes seems that we will never know all there is to be learned about any one of these diseases, but as Pasteur, who was at least in part a medical zoologist, remarked, "To travel hopefully is a better thing than to arrive, and the true success is to labor."

R. W. HEGNER
SCHOOL OF HYGIENE AND PUBLIC HEALTH,
THE JOHNS HOPKINS UNIVERSITY

THE RUMFORD FUND

THE following is a brief history of the Rumford Fund, as well as of the purposes for which it was created and has been maintained.

Benjamin Thompson was born at Woburn, Mass., in 1753, and studied at Harvard College, being much interested in scientific subjects. He was a teacher in schools at Wilmington, Mass., and at Rumford, N. H. He went to England in March, 1776, and carried on there a series of scientific studies, the results of which were communicated to the Royal Society. He was elected a fellow of that society in 1779.

In 1785, he entered the service of Prince Maximilian, the Elector of Bavaria. He introduced a number of important reforms into that country, while also carrying on an important series of scientific researches. One result of these researches was a demonstration of the equivalence between heat and mechanical work. He reclaimed a large area of barren land at Munich, and formed it into a fine park, which he subsequently gave to the city and which is still known as the "English Garden." In 1791, he was invested with the rank of a Count of the Holy Roman Empire, and chose the title of Rumford, the New Hampshire village in which he had taught as a youth, and in which the family of his wife had resided.

In 1802, he removed to Paris, where he met and married his second wife, who was the widow of the celebrated chemist, Lavoisier. It was in 1794 that the French revolutionary government had sentenced Lavoisier to death under the guillotine, at what is now the Place de la Concorde in Paris.

Count Rumford founded the Rumford Research Medals of the Royal Society in London and of the American Academy of Arts and Sciences in Boston. He also founded a Rumford professorship in science at Harvard University. During his life, he made numerous contributions to economics, physics, meteorology and chemistry. He died at Auteuil, Paris, in 1814.

The American Academy of Arts and Sciences has continued to administer the Rumford Fund, by awarding premiums and grants, in aid of researches in light and heat. The academy maintains a standing committee of seven fellows, known as the Rumford Committee. This committee, from time to time, recommends to the academy the award of the Rumford premium or medal to persons in North America or any of the American islands, who have notably contributed to the sciences of heat or light. The committee also considers all applications for grants from the income of the fund in aid of research connected with those sciences.

Since 1839, the academy has made thirty-two awards of the Rumford premium to scientific investigators. It has also made nearly 250 grants of money to researchers, varying in amount between \$25 and \$750, but averaging about \$260 each. These grants are for apparatus, materials or experimental equipment. They are also made towards costs of printing in the publication of researches. Only in very rare cases have grants been made towards the payment of assistants in carrying on such researches.

The subjects of research aided by the Rumford Fund are light and heat. More recently, the subject of X-rays has been accepted as coming within the scope of the fund.

Recipients of grants for investigations are ex-