INTRODUCTION TO PARASITOLOGY

With Special Reference to the Parasites of Man

BY

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PREFACE

Twenty-two years ago the writer prepared a book on " Animal Parasites and Human Disease " designed to set forth the many interesting and important facts of human parasitology in a readable form which would make them available for a wide range of intellectually curious readers. It was felt that there was a tendency of scientists to blaze trails into unknown territory so rapidly that the general public was left too far behind. Only specialists could understand the importance or significance of new discoveries, or make efficient use of older ones. Such a condition lessens the utilitarian value of discoveries which if more widely understood would contribute to the welfare of mankind, and it also makes the further progress of the scientist more difficult. Scientific work flourishes best when intelligent public sentiment is behind it, and such sentiment is dependent upon capitalization of results already achieved, and a clear understanding of future goals.

Although " Animal Parasites and Human Disease " was not so widely taken up by the general public as anticipated, it was at once accepted as an introductory textbook in parasitology, and year by year it has been adopted by more and more normal schools, colleges, and universities throughout the country. With the fourth edition the book was entirely rewritten, rearranged to serve its function as a textbook more efficiently, and presented under a new title, " Introduction to Human Parasitology." Twenty years ago parasitology was taught in only a few universities; today it is presented as a popular course in over a hundred schools, and thousands of students go out into the world every year with a clear understanding of the basic facts concerning such things as syphilis, amebiasis, malaria, hookworms, and transmission of disease by insects. The writer hopes that this book has played at least a small part in bringing this about, partly by stimulating the interest of students, and partly by making easier the task of the teacher.

The rapid advance of knowledge in the field of parasitology has made it necessary to revise and rearrange the book about every four years. When the fourth edition was prepared in 1930, rewritten from cover to cover, it was thought that the rapid advance of the previous years could not continue, but this proved not to be true. In 1936 the book

was again entirely rewritten, and in the four years since then so many advances have been made that a complete rewriting again becomes necessary. This fact has been taken advantage of to make a number of other changes in the content and arrangement of the book to meet the desires of many of the teachers who use it.

The scope of the book has been widened. References have been made throughout the text to the important parasites of domestic animals in order to give a broader background of knowledge and to make the book more useful as a preliminary to a course in veterinary parasitology. To indicate its broader field the name of the book has undergone a further evolution and is now " Introduction to Parasitology, with Special Reference to Human Parasites."

At the request of a number of users of the book the general bibliography at the end of the volume has been replaced by a brief list of references at the end of each chapter. These lists are not, of course, intended to be in any way complete, but merely to give the student an entrée to the literature of the subject. Included are articles or books which give extensive reviews or summarizations of the subjects with which they deal, or which contain good bibliographies; also included are a few of the more recent contributions of importance which would not be found in the bibliographies of the other works cited.

Since many teachers have felt that more adequate classification of parasites would be a desirable feature of the book, this phase of the subject has been given more attention. The outlines of classification, however, have been incorporated in small type, so that they do not interfere with the general readability of the text and can be omitted if not needed. In the section on arthropods a number of simple keys to important groups of genera or species have been included. These, too, are set off in small type so they can easily be omitted if their use is not required.

Although the spirochætes are now quite generally regarded as related to bacteria rather than protozoa, and their omission from a book dealing with parasites of animal nature would be logical, a large proportion of the users of the book, when asked about the advisability of omitting them, expressed a strong desire to have them retained. The section on syphilis has been given even more emphasis than before; the " coming-out party " which Surgeon-General Parran recently gave this subject has created public interest in it at the present time. Sections dealing with other diseases important in our own country have been somewhat expanded, e.g., those on amebiasis, malaria, trichiniasis, hookworm, and arthropod-borne rickettsial diseases.

As in earlier editions, no attempt has been made to give complete

descriptions of all the parasites dealt with, though where it is particularly important to distinguish between related or similar species, sufficiently detailed descriptions or figures have been given to make a correct identification possible. Discussions of correct scientific names and synonymy have been omitted because of the writer's opinion that they have no place in an introductory text. An effort has been made to use scientific names which are most generally accepted as correct. In cases where names other than the ones now accepted as correct under the rules of zoological nomenclature have long been in common use, these names are given in parentheses.

Throughout the book special emphasis has been laid on the biological aspects of the subject. Considerable space is devoted to life cycles, epidemiological factors, interrelations of parasite and host, and underlying principles of treatment and prevention, rather than on such phases as classification, nomenclature, morphology, etc., which occupy much of the space in some textbooks of parasitology. The book is an introductory one, and as such is more concerned with fundamental facts and principles than with the details that would interest a specialist. It has been suggested by some that the sections on treatment might be left out entirely. So far as specific and detailed directions for treatment are concerned, this has been done except in a few places; it is, however, important even for a beginner to know whether or not a parasitic infection is amenable to treatment, even if the details are not presented, and it is properly within the scope of an introductory book on parasitology to discuss the general *principles* of treatment, such as the specific reaction between certain parasites and certain drugs, the manner in which drugs reach the parasites, the mechanism by which the effect is brought about, and factors which contribute to success or failure. These are true biological aspects of the subject.

Parasitology has grown so rapidly in recent years and covers such a wide field, that it is difficult to go very far into the subject within the limits of one book. Nevertheless it is the writer's belief that a comprehensive integrated account of the entire field is much the most desirable method of approaching the subject at the start. Protozoology, helminthology, and medical entomology have many interrelations, and no one of them can be satisfactorily pursued very far without some knowledge of the others. But for more advanced work a comprehensive text is too cumbersome; the subject naturally splits into its three component parts. There are excellent up-to-date textbooks available on each subject. For the parasitologist who wishes to continue in the protozoological field, Wenyon's " Protozoology " (2 volumes) or Knowles' shorter " Introduction to Medical Protozoology "

can be especially recommended; for the helminthologist, Faust's "Human Helminthology"; and for the medical entomologist, Herms' "Medical Entomology," Riley and Johannsen's "Medical Entomology," or Matheson's "Medical Entomology."

In "Sources of Information" at the end of the book is a list of the leading journals in which important articles on parasitology frequently appear.

Particular attention is called to five of these publications — the *Tropical Diseases Bulletin,* which reviews practically all current work in the field of human parasitology, especially protozoology and helminthology; the *Review of Applied Entomology, Series B,* which contains abstracts of all important work on medical and veterinary entomology; *Helminthological Abstracts,* containing abstracts of all important work in helminthology; the *Journal of the American Medical Association,* which gives references to all articles in the leading medical journals of all countries, and reviews many of them; and *Biological Abstracts* in which abstracts of interest in human parasitology will be found in the section on parasitology, and in appropriate sub-sections under Systematic Zoology. Any of the reprints or pamphlets received by the Bureau of Hygiene and Tropical Diseases, which publishes the *Tropical Diseases Bulletin,* will be sent on loan to any part of the world when directly applied for, and the American Medical Association will likewise lend any of the periodicals in its library to any member of the Association. The five periodicals mentioned, on account of their scope and thoroughness, are of inestimable value to anyone who attempts to keep pace with the progress of parasitology.

The writer takes pleasure in acknowledging the great assistance which he has obtained from these journals in the preparation of this book, which in fact could not possibly have been done without them. There are, however, few if any of the journals listed under "Sources of Information," or of books or articles listed under chapter references, which have not been drawn upon for either information or illustrations, or both. All of them, collectively, have made this book possible, and to them, and to the workers who contribute to them, are due, therefore, not only the thanks of the writer, but also the thanks of everyone who may profit in any way by the present volume.

The forerunner of the present book, "Animal Parasites and Human Disease," was very kindly read by three eminent authorities, who freely gave the benefit of helpful suggestions and criticisms, namely, Professor Gary N. Calkins, Professor of Protozoölogy at Columbia University, the late Dr. B. H. Ransom, of the Zoölogical Division of the U. S. Bureau of Animal Industry, and Dr. L. O. Howard, Chief of

the U. S. Bureau of Entomology, since retired. These men helped materially to round off the rough corners, and fill in the chinks, of the sections on protozoa, "worms," and arthropods, respectively. The benefits of their assistance have been carried on into the present book.

In conclusion I wish to express my appreciation of the kindness of many friends and colleagues who have helped in weeding out errors and in suggesting changes in the text. I hope that those who make use of the book will continue to offer criticisms or suggestions; they will be given careful consideration in future editions of the book.

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HOUSTON, TEXAS
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CHAPTER I

INTRODUCTION

One of the most appalling realizations with which every student of nature is brought face to face is the universal and unceasing struggle for existence which goes on during the life of every living organism, from the time of its conception until death. We like to think of nature's beauties; to admire her outward appearance of peacefulness; to set her up as an example for human emulation. Yet under her seeming calm there is going on everywhere — in every pool, in every meadow, in every forest — murder, pillage, starvation, and suffering.

Man often considers himself exempt from this interminable struggle for existence. His superior intelligence has given him an insuperable advantage over the wild beasts which might otherwise prey upon him; his inventive genius defies the attacks of climate and the elements; his altruism, which is perhaps his greatest attribute, protects, to a great extent, the weak and poorly endowed individuals from the quick elimination which is the inevitable lot of the unfit in every other species of animal on the earth. Exempt as we are, to a certain extent, from these phases of the struggle for existence, we have not yet freed ourselves from two other phases of it, namely, competition among ourselves, resulting in war, and our fight with parasites which cause disease.

There were optimists who thought that after the last great war had burned itself out in 1918 there would never again be a similar spectacle on the earth, but the 1940 catastrophe is clear evidence that this phase of our struggle for existence constitutes a greater peril today than ever before. But while science has been making our struggles with each other constantly more terrible and devastating, it has in the meantime largely freed us from the helpless bondage in which we were once held by the organisms of disease. Here progress has been almost entirely one-sided, for the slow process of evolution on which our parasitic enemies must depend is no match for the swift development of advantages afforded by human ingenuity; we purposely refrain from saying

" intelligence," since the application of our ingenuity to destruction of each other can hardly be construed as intelligence.

One by one the diseases which formerly held the world in terror, or made parts of it practically uninhabitable, have had their power broken by the onslaught of modern scientific research. With few exceptions, so far as man and his domestic animals are concerned, the enemy has been discovered; his resources and limitations are known, and his tactics are understood. We may be reasonably sure that at least in civilized communities such diseases as smallpox, plague, yellow fever, and typhoid will never again break loose in devastating epidemics, although they will continue to snipe at us from their ambushes in field and jungle, or to take advantage of weakened defenses in local areas or in times of stress.

Although some of the most spectacular diseases — such as typhoid, cholera, smallpox, and diphtheria — are caused by bacteria or viruses not included within the scope of this book, the importance of animal parasites and of arthropod vectors of disease is enormous. Malaria is the most important of all human diseases, and no one questions the importance of trypanosomiasis, leishmaniasis, amebic dysentery, or piroplasmosis among protozoan diseases; or of hookworm disease, filariasis, schistosomiasis, or scabies among diseases caused by higher organisms.

Even many of the diseases that are caused by bacteria or viruses owe their importance and often their very existence to arthropod vectors which fall within our field of interest. Plague, tularemia, typhus, spotted fever, trench fever, relapsing fever, yaws, yellow fever, dengue, and sandfly fever are outstanding among these. The recent demonstration by Shope that the virus involved (along with a bacillus) in the production of swine influenza has an inter-epidemic reservoir in lung worms (Metastrongylus) is a revelation which may prove to be only the beginning of knowledge of the rôle of worms in the epidemiology of human and animal disease.

But even many of the lesser lights among parasites, of rarer occurrence or of local distribution, are of importance to the human race far out of proportion to popular interest or knowledge of them. Parasitic infections that affect the health of millions of people and sap the vitality of entire nations have never been heard of by many otherwise educated people. Yet the affairs of people in foreign countries are no longer inconsequential to us. The human animal, endowed by nature with a wanderlust and an itchy foot, is today traveling farther, faster, and oftener, by fast trains, ocean liners, and airplanes, than he has ever traveled before. Even in the old days when a trip from continent to

continent took weeks or months, the dispersal of parasites was common. The ancient traders of Egypt and Syria, searching the Far East for spices and pearls, brought back with them filariæ; centuries later the Europeans, exploring America for gold, brought back syphilis; negroes, brought from Africa as slaves, very likely introduced hookworm, schistosomes, guinea worms, filariæ, and possibly yellow fever, to the Western Hemisphere. It was worth a passing thought that, after years of absence, rabies was reintroduced into England by a dog brought from France in an airplane. Parasitic diseases are no longer looked upon as peculiar to the tropics. France has some of the most highly malarial territory in the world, and the dysentery ameba occurs with discomforting regularity in some 10 per cent of the inhabitants of the United States.

With the progress of civilization, however, many human parasites are gradually falling by the wayside. In part this is the result of conscious effort to eradicate them, but in part it is incidental to sanitary improvements with civilization; sanitation has already made life difficult for many parasites in the north temperate zone, and the tropics are slowly but surely following suit. M. C. Hall says "The welfare of the louse was imperilled when the Saturday night bath supplanted occasional immersion from falling into the water, and the louse was doomed when American plumbing laid the foundation for a daily bath or even a morning and night tub a day. Shaving deprived the human ectoparasite of a protected forested area. *Tænia solium* took the road to extinction when the mythical Chinaman burned down the house, and ate the incinerated pig and pronounced it good, and has had no chance against a meat inspection system which tanks all cases of *Cysticercus cellulosæ*. The substitution of the privy and toilet for the rush-covered floor of the Middle Ages spelled present extinction for human ascarids and hookworms. . . . The city water supply does not serve the parasite as does the pond and stream." Without any special campaigns to eradicate them, cooties and worms have become almost negligible factors in the civilized countries of the north temperate zone; the cook, the barber, the laundryman, and the plumber have made their lives too insecure.

As Hall points out, man is, in this respect, in a far better situation than his domestic animals. The latter soil their table with their feces; they must eat uncooked food and drink largely from ponds and streams; their hairy bodies provide ideal playgrounds for ectoparasites; and their bathing habits are those of the small boy — compulsory baths only, as a rule. Their domestication and increasing concentration lead to increasing parasitization. Under the law of chance, says Hall, the

parasite egg that had to pursue its host to a new bed-ground five miles away was out of luck, whereas when millions of eggs are sowed on limited pastures, the parasites have all the advantage. In the case of human parasites, increased concentration has a directly opposite effect, due to improved water supplies, control of foods, and sanitary sewage disposal.

But let us not think for a moment that the battle is won. Not only are there some diseases which still baffle our attempts to cure them or to control them, or even to understand their nature, but those which we already know how to control are by no means subdued. Plague continues to take a toll of life in India amounting to at least several hundreds of thousands a year; malaria even today destroys directly or indirectly millions of people every year, and more or less completely incapacitates many millions more; syphilis is estimated to exist in close to 10 per cent of the inhabitants of the United States, and to be one of the principal causes of insanity, paralysis, stillbirths, and barrenness; hookworms still infect and render more or less imperfect over half a billion people in the world; — and these are all diseases the causes of which are known, the means of transmission recognized, methods of prevention understood, and the cure of which, with the exception of plague, is possible.

It is evident that there is need not only for additions to our knowledge of the cause and control of diseases, but also, and perhaps even more pressing, a need for the efficient application of what we already know. Apathy to parasitic diseases is largely the result of ignorance concerning them. Our minds are relatively impervious to new ideas; we prefer to cling to traditions. When we consider that practically all our knowledge concerning parasites has been obtained within the last hundred years, and an astonishing amount of it within the last twenty, it is not surprising that mistaken notions of our grandparents still compete successfully with modern scientific knowledge. It takes decades, if not centuries, to modify or correct popular notions. One need only mention the popular disbelief in evolution, the credulity with respect to the origin of " horse-hair snakes " from horse hairs in water, and the existence of anti-vaccination societies which denounce vaccination as an impractical and illogical proceeding. Little wonder that popular skepticism still exists with respect to the transmission of malaria by mosquitoes, and that people still fear the miasmas of damp night air.

History

Early views. Up to the middle of the seventeenth century knowledge of parasitology was limited to recognition of the existence of a few

self-asserting external parasites such as lice and fleas, and a few kinds of internal parasites which were too obvious to be overlooked, such as tapeworms, ascaris, oxyuris, and the guinea worm. These parasites were, however, thought to be natural products of human bodies, comparable with warts or boils. Even such immortal figures in parasitology as Rudolphi and Bremser at the beginning of the nineteenth century supported this idea. In Linnæus' time this view gradually gave way to another — that internal parasites originated from accidentally swallowed free-living organisms. Flukes, for instance, were thought to be " land-locked " leeches or " fish "; in fact, the name fluke is said to come from the Anglo-Saxon " floc," meaning flounder. Until the middle of the seventeenth century the necessity for parents was regarded as a handicap placed upon the higher vertebrates alone. Biology students struggling with required insect collections sometimes wonder how Noah ever succeeded in collecting all the species which must have been known even in his day for rescue in the Ark, but that was no worry of Noah's; he anticipated that insects, worms, snakes, and mice would be spontaneously generated after the flood as well as before.

Redi. The grandfather of parasitology was Francesco Redi, who was born in 1626. In the latter half of the seventeenth century he demonstrated to an unbelieving world that maggots developed from the eggs of flies, and that even ascaris had males and females and produced eggs. He extended the idea of parenthood so far that it is really remarkable that its universal application, even to bacteria, had to wait for Pasteur's ingenious experiments two centuries later. Although Redi's recognition of obligatory parenthood in lower animals was his outstanding achievement, he was the first genuine parasite hunter; he searched for and found them not only in human bowels but in other human organs, in the intestines of lower animals, in the air sacs of birds, and in the swim bladders of fish. In this first parasitological survey we find all the principal types of parasites in each of the great groups recognized today. Among the numerous parasites first described by him was the liver fluke (Fasciola), so the subsequent naming of rediæ after him was a fitting tribute. The first important fruit of Redi's work, as a matter of fact inspired by him, was the demonstration in 1687 by two of his Italian countrymen, Bonomo and Cestoni, that scabies was a disease caused by mites burrowing and reproducing in the skin, and was spread by transmission of the mites. This was the first demonstration of a specific cause for a disease, and was a clean break from the divine, humoral, or other ancient theories of the spontaneous origin of disease; it extended the idea of parenthood to disease.

Leeuwenhoek. This same half-century marked the origin of protozoology, for it was then that the Dutch lens-grinder, Leeuwenhoek, perfected microscopes which enabled him to discover and describe various kinds of animalculæ, many recognizable as Protozoa, in rainwater, saliva, feces, etc.; among the organisms in feces he discovered what was probably a Giardia, although the first protozoan definitely recognized as a human parasite was *Balantidium coli,* discovered by Malmsten in Sweden in 1856, nearly two centuries later.

Rudolphi. In spite of the work of these pioneers, parasitology made little progress until about a century later, when Rudolphi came upon the scene. He was born in Stockholm in 1771, but did most of his work in Germany. He did for parasitology what Linnæus did for zoologists in general; he collected and classified all the parasites known up to his time. Zeder, in 1800, recognized five classes of worms which Rudolphi named Nematoidea, Acanthocephala, Nematoda, Cestoda, and Cystica; the last had to be discarded about 50 years later when bladderworms were found to be the larval stages of the Cestoda.

Developments to 1850. During the first half of the nineteenth century numerous new species of parasites were discovered and described by Dujardin, Diesing, Cobbold, Leidy, and others. Meanwhile, observations on the life cycles of flukes and cestodes were being made. O. F. Muller discovered cercariæ in 1773 but thought they were protozoa; Nitzsch, in 1817, recognized the resemblance of the cercarial body to a fluke and regarded the creature as a combination of a Fasciola and a vibrio; Bojanus, in 1818, saw the cercariæ emerge from " royal yellow worms " in snails, and Oken, the editor of *Isis,* in which the work was published, felt willing to wager that these cercariæ were the embryos of flukes; contributions by Creplin, von Baer, Mehlis, von Siebold, von Nordman, and Steenstrup finally added enough pieces to the puzzle so that by 1842 the general pattern of the picture could readily be seen.

Meanwhile, light was also shed on the true nature of bladderworms and hydatids. As the result of observations by Redi, Tyson, Goeze, Steenstrup, von Siebold, and van Beneden, their relationships with tapeworms gradually became apparent, but up to 1850 they were generally regarded as " hydropically degenerated " as the result of development in an abnormal host into which they had accidentally strayed. It was during this period also that Trichinella was discovered in human flesh by Peacock (1828), and in pigs by Leidy (1846); that Dubini discovered human hookworms (1842); that Hake discovered the oöcysts of Coccidia in rabbits; that Gluge and Gruby discovered trypanosomes in frog blood (1842); and that Gros found the first human ameba, *Endamœba gingivalis* (1849).