Introduction to PARASITOLOGY

With Special Reference to the Parasites of Man

9th Edition

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Preface

In 1918 I prepared a book on *Animal Parasites and Human Disease* designed to set forth interesting and important facts of human parasitology in a readable form that would make them available to a wide range of intellectually curious readers. Although not so widely taken up by the general public as anticipated, this book was at once accepted as an introductory textbook in parasitology, and year by year was adopted by more and more normal schools, universities, and medical schools throughout the country. With the fourth edition, in 1930, 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*. The book was, however, widely used as a *general* introductory textbook, so with succeeding editions its scope has been broadened to include more and more references to, or discussion of, parasites of lower animals, particularly those of importance in veterinary medicine. To reflect this extension the title was again changed in the sixth (1940) edition to its present form. The parasites of man are still most fully considered and are used as examples of their respective systematic groups, but all the parasites of veterinary importance are at least mentioned, and many of them are discussed. It would obviously be impossible to make detailed reference to parasites of other animals in an introductory textbook, but general statements are made concerning the occurrence of representatives of groups of parasites in various types of hosts. For completeness, such groups as the monogenetic flukes, strigeids, Cestodaria, etc., are discussed in this edition.

When *Animal Parasites and Human Disease* was first published, parasitology was taught in only a few universities, but there was a steady, gradual increase in the attention given to the subject up to about the beginning of World War II. I hope that this book may have played some part in the development of this gradually increasing popularity by stimulating the interest of students and by making easier the task of the teacher. During World War II and for several years thereafter, there was a very sharp upturn in interest in parasitology, due to a belated realization of the importance of the subject as a factor in world health and in the welfare of military expeditions. With the advent of

World War II, parasitology took its rightful place of prominence in the community of sciences and came of age in America. During the war parasitological problems all over the world presented themselves for immediate solution, and the neglect with which parasitology had been treated in the past became painfully apparent. There were distressingly few individuals who had had experience with even such common parasitic diseases as malaria or amebiasis, not to mention schistosomiasis, leishmaniasis, scrub typhus, etc., which few had ever even heard of. Our military forces performed a veritable miracle in correcting the situation. Not only were thousands of people trained for the efficient application of what was already known, but research in parasitology flourished as never before.

Unfortunately, in the last few years interest in parasitology in the United States, particularly unfortunately in medical schools, has tended to fall back to its inadequate prewar status. We have tended to demobilize in our fight against parasites, just as we prematurely demobilized militarily immediately after the war. We have realized our error in the latter instance, but have not yet realized it in the former, but unless we do something about our neglect of research and education in parasitology we shall inevitably regret it, and perhaps much sooner than we think. The reasons for this are outlined in Chapter 1 (Introduction) and need not be repeated here. Suffice it to say that even though parasitic diseases at present are of relatively minor importance within the boundaries of the United States, they are still of vast importance to us, and we are very short-sighted in neglecting them as we are now tending to do.

The rapid advances in knowledge in the field of parasitology, which have made it necessary to revise and largely rewrite this book every four to six years since it first appeared in 1918, have continued. In the six years that have elapsed since the eighth edition was written, unprecedented advances have been made in knowledge of the treatment and control of parasitic diseases, and innumerable other smaller additions to knowledge have been made, so again the book has been extensively revised. A number of chapters or sections have been entirely or almost entirely rewritten, and changes have been made on every page. There have been no changes in arrangement except to split the chapter on trematodes into three chapters. New and up-to-date systems of classification have been adopted throughout. An effort has been made to extend references to and consideration of parasites of veterinary importance, and the general aspects of parasitology have not been neglected. Most of the illustrations which were not new in the eighth edition have been improved or are entirely new.

As in previous editions, a chapter on spirochetes has been included,

although these organisms are now quite generally regarded as bacteria rather than Protozoa. Since the spirochetes are given inadequate treatment in most bacteriology books and are repeatedly referred to in this book in connection with their arthropod vectors, most parasitology instructors prefer to have them included. Also retained and somewhat enlarged is the section on arthropod-borne bacteria, rickettsias, and filtrable viruses, in order to give the student a more comprehensive view of these disease agents and their relations to their vectors than can be gathered from disjointed discussions of them in connection with their individual vectors.

Only enough classification and taxonomy are included to give the student an understanding of the general relationships of the parasites considered. Outlines of classification of major groups and a number of simple keys to important groups of genera and species of arthropods have been set in small type so that they do not interfere with the readability of the text and can be omitted if not considered necessary. Most students, however, will benefit from a little experience in the use of keys for identification.

Discussions of correct scientific names and synonymy have been mostly omitted as inappropriate in an introductory textbook. An effort has been made to use scientific names which are most generally accepted as correct. Some of the names used, e.g., *Entamoeba* and *Dibothriocephalus latus,* have not yet been accepted by the majority of American authors, although I feel that eventually they will be. In such cases the instructor can, of course, have his students employ the more widely used names if he wishes; no harm will have been done by calling attention to the fact that there *are* differences of opinion. Names that have long been in common use, although not now accepted as correct under rules of zoological nomenclature, 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, and morphology. This book, as an introductory one, is more concerned with fundamental principles than with the details that would interest a specialist. Clinical features of the diseases caused by the parasites are not dealt with sufficiently to satisfy medical students; these are left for the professor to fill in to the extent he desires, but the underlying reasons for the pathologic effects are adequately discussed. Some therapeutic details, also, are omitted, although the availability of effective drugs, their mechanism of action, reasons for failure, effects on the host, etc., are considered.

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 my 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. For more advanced work a comprehensive textbook is too cumbersome; the subject naturally splits into its three component parts.

A brief list of references is provided at the end of each chapter for the student who wishes to pursue the subject farther. Included are books or papers 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 bibliographies of the other works cited, and which contain information beyond that cited in the present book. In the text, references that are included in the bibliographies have the date cited in parentheses; other references are usually made in the form "Smith in 1948 . . . ." It should not be too difficult for a student to trace down most of these references, if he wishes, through such journals as *Biological Abstracts, Helminthological Abstracts, Tropical Diseases Bulletin, Review of Applied Entomology, Index Medicus, Veterinary Bulletin,* etc.

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 the periodicals mentioned in the preceding paragraph. The *Tropical Diseases Bulletin* reviews practically all current work in the field of human parasitology, especially protozoology and helminthology. The *Review of Applied Entomology,* Series B, contains abstracts of all important contributions in the field of medical and veterinary entomology. The *Veterinary Bulletin* reviews important work on diseases of domestic animals. *Biological Abstracts* contains abstracts of interest in parasitology in its sections on parasitology, sanitary entomology, and in appropriate subsections under systematic zoology. The *Index Medicus* and *Quarterly Cumulative Index Medicus* list references to nearly all writings of medical interest, and the *Journal of the American Medical Association* lists references in all the leading medical journals of the world and reviews many of the more important articles. These valuable bibliographic and abstracting journals are necessary for anyone who attempts to keep pace with the progress of parasitology; without them this book could not have been kept up-to-date.

There are few if any of the journals listed under "Sources of Information" or of books or articles listed under chapter references that have not been drawn upon for help in the preparation of this book. All of them, collectively, have made the book possible, and to their authors or contributors are due therefore the thanks both of the writer and of everyone who may profit in any way from the present volume.

Most of the new illustrations in this edition were made by Mr. George Newman of the University of Texas Medical School.

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.

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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 extinction 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.

We have made far more progress toward the latter phase than toward the former. The very inventive genius that has freed us from the great epidemics of infectious disease—cholera, plague, smallpox, yellow fever—that even in the nineteenth century spread terror in the world, has made our struggles with each other constantly more devastating and perilous, until today they threaten complete destruction of our civilization. No epidemics of disease ever threatened anything like that, even in the early days of our civilization when changing ways of life gave epidemics opportunities they never had had before in the history of the world, and when we had not yet developed countermeasures against them.

But our concern in this book is with the more auspicious struggle with parasites. Here progress has been largely 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. With few exceptions as far as man and his domestic animals are concerned, the enemy has been discovered, his resources and limitations known, his tactics understood, and weapons of offense and defense developed. Progress is not *always* one-sided, however. When we developed powerful chemotherapeutic drugs and deadly residual insecticides, we thought we had achieved insuperable advantages, but bacteria and trypanosomes countered with drug resistance, and flies with chemical tolerance. So we invent new chemical weapons and the parasites and vectors new defenses, but the latter seem able to work faster than our chemists.

There is another disquieting aspect of the matter. Most of our progress has been medical or chemical—development of therapeutic and prophylactic drugs, vaccines, and insecticides. These successes, as Vaucel (*WHO Newsletter,* April 1954) pointed out, along with good environmental and social conditions, have been adequate to protect the privileged Europeans and Americans even when living in undeveloped and underprivileged countries, and also the infinitesimal fraction of natives in these countries (usually called the tropics, but not confined to that area) who live European lives. Our medical successes have had much less effect on the millions of people who are living under practically the same conditions as they lived under several thousand years ago. Some of our great medical victories *have* affected backward populations, but only when they have not involved important changes in the age-old ways of life. The conquest of malaria by residual sprays is an outstanding example; houses are sprayed, but not changed, and everything else remains the same. Sleeping sickness has been greatly reduced in large areas in Africa, but all the native population had to do was to present itself for treatment. Yellow fever in South America, plague in Madagascar, kala-azar in India are other examples of the same thing. In Latin America, however, more progress has been made, concomitant with improvement in economic conditions. Houses are not merely sprayed to kill the bugs that transmit Chagas' disease; efforts are made, with spectacular success in some places in Brazil, to make the houses more suitable for human beings and less suitable for the bugs.

Because of his way of life, the white man never suffered seriously from what he considers the minor plagues of the tropics, caused by filariae, *Onchocerca,* guinea worm, hookworms, *Ascaris,* schistosomes, *Fasciolopsis,* trypanosomes, *Leishmania,* and such diseases as relapsing

fever, yaws, and tropical ulcer, to mention only a few. But these are all part and parcel of the native's daily life; he cannot avoid them, yet they incapacitate him for work, blind him, mutilate him, and make his life miserable. So little have most of these diseases affected the white man that most of them are probably totally unfamiliar to students starting to study this book.

So, in spite of some spectacular successes, the human race still has far to go in the process of emancipation from parasitic disease. It will require improvement in social and economic conditions of great masses of people—the provision of wells, latrines, decent housing, refuse disposal, proper food, shoes, and elimination of insect vectors—and also education. Of all these items, probably two stand out in importance: proper food, since malnutrition not only causes disease per se, but is a very large factor in ability to fight other diseases (see p. 25); and education, because only by knowing what is dangerous, and why, can mankind hope to win in the struggle with disease.

In spite of the fact that most of the parasites dealt with in this book are now relatively scarce, localized, or entirely eliminated in the United States, it does not follow that they are of little importance to us. In these days, with international travel as common as interstate travel was a generation ago, many a home-town physician has to deal with patients suffering from diseases which previously had been only names to him. Also the opportunity for dissemination of parasites or vectors entering as stowaways in airplanes, or on or in the bodies of passengers, is greater than ever before. Even when it took weeks or months to go from continent to continent, dispersal of parasites was common. Traders brought filariasis from the South Seas to Egypt, slaves brought hookworms and schistosomes from Africa to America, and trading vessels carried yellow fever from the American tropics to New York and Philadelphia. What can be expected when we can have breakfast in Colombia and supper in Florida?

But this is not all. Isolationism is gone, whether we like it or not. The world is fast becoming an economic unit, or at least two competing economic units, and a disease that affects the production of rice in Burma or meat in Argentina or coffee in Brazil inevitably affects us economically, and our stake in the welfare of undeveloped countries, large already, will inevitably increase. We have less than 10 per cent of the world's population and 8 per cent of its area, but we use 50 per cent of the produce of the Free World. We depend on foreign sources for over 40 per cent of our minerals, and 10 per cent of our other raw materials—soon it will be 20 per cent. Undeveloped areas of the world—the areas principally affected by parasitic diseases—supply 60

per cent of our imports and 40 per cent of our exports. Obviously, then, the diseases that profoundly affect the health and productivity of these areas are of very real concern to us. The diseases from which underprivileged people suffer are chronic ones, as Wright (1951) pointed out, and sick or incapacitated people are a greater drain on productivity than dead ones.

We cannot credit all our relative freedom from parasitic diseases to our own purposeful efforts. With the progress of civilization, many human parasites have gradually been falling by the wayside, but the less civilization has advanced in an area the fewer have fallen. As M. C. Hall said, the louse had its welfare imperiled when the Saturday night bath supplanted occasional immersion from falling into water; it had a struggle for survival when modern plumbing and laundering facilities laid the foundation for a daily bath even in winter, and clean clothes once a week. The housefly got a severe setback when the automobile replaced the horse, and when modern sewage systems were developed. Mosquitoes suffered with the advent of agricultural drainage and reclamation schemes. With the reduction of these vectors went reduction in the protozoan and bacterial diseases they disseminate—malaria, epidemic typhus, dysentery, etc. Of course, the advent of DDT greatly speeded up the process in some cases, but epidemic typhus had disappeared and malaria had become quite limited geographically in this country *before* that magic chemical and allied substances were discovered. Substitution of sanitary toilets for the rush-covered floors of the Middle Ages and the shaded soil of unsanitated areas spells extinction for hookworms and *Ascaris*. Cooking and refrigeration make life more precarious for *Trichinella* and *Taenia*. Improved water supplies and good sewage disposal are dangerous to most intestinal infections. To the extent that these concomitants of civilization have become part of the way of life of a people, parasitic infections have decreased even without new insecticides, new chemotherapeutics, or new vaccines. These specifically developed weapons have practically completed the white man's freedom from most of the infectious diseases that he once justifiably feared; radical changes have been wrought even since the last edition of this book was published in 1949.

For our domestic animals, on the other hand, domestication and increasing concentration have meant increasing parasitization, for they soil their table with their feces, they eat uncooked food, they drink contaminated waters from ponds and streams, they bathe only by accident, and they have hairy bodies that provide ideal playgrounds for ectoparasites. The parasite egg that had to pursue a deer or antelope

to a new bedground five miles away was out of luck, said Hall, whereas when millions of eggs are sowed on limited pastures, the parasites have all the advantage. For human parasites, increased concentration had an opposite effect owing to better opportunity for improved water, control of foods, and sanitary sewage disposal. But the parasites of the roaming deer and antelope are in a less vulnerable position than those of cattle or sheep. Some years ago the U. S. Department of Agriculture exterminated Texas fever in the United States, and eliminated *Boöphilus annulatus,* but it took years of hard and expensive work. Today warbles, hornflies, screwworms, sheep bots, and cattle lice could probably be exterminated in a fraction of the time and at much less cost.

In spite of spectacular advances in our struggle with parasites, it is obvious, then, that the battle is far from won. In 1947 Stoll made the startling estimate that there are in the world today 2200 million helminthic infections—enough for one for every inhabitant if they were evenly distributed. We have sufficient knowledge to be able to control most, though certainly not all (schistosomiasis and poliomyelitis are conspicuous exceptions) of the infectious diseases of ourselves and of our domestic animals, but they are still mostly unsubdued in vast areas of the world. There is not only need for additions to our knowledge of the causes 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. Though this ignorance is most abysmal in still-primitive peoples of undeveloped countries, it is by no means absent in our own country. Some of our neighbors still think that malaria results from damp night air, that vaccination should be done away with, that animal experimentation is unjustified. After all, it is only 200 years since our Pilgrim Fathers boiled witches instead of water to control cholera!

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,* pinworms, and guinea worms. These parasites were, however, thought to be natural products of human bodies, comparable to warts or boils. Even such immortal figures in parasitology as Rudolphi and Bremser at the beginning of the nineteenth century supported this idea. In Linnaeus' 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 "landlocked" 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.

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 animalculae, many recognizable as Protozoa, in rain water, 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 Linnaeus 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.