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Biochemical, Immunological and Epidemiological Analysis of Parasitic Diseases

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One of the Editors Dr. Das likes to dedicate his works to his great teacher ***Late Dr. H.N. Ray****, P.R.S., Ph.D. (Lond), F.Z.S., F. N.I., one of the internationally famed scientists of his time and to his father* ***Late Dr. M.R. Das****, M.B. (Cal) who was a legendary figure in the field of medical profession.*

Dr. Amit Chattopadhyay likes to dedicate his contribution in this book to his lovable son ***Master Ayush Chattopadhyay****.*

We, Dr. Nitisranjan Das and Dr. Amit Chattopadhyay, are most fortunate to work with the late Professor Dr. P.K. Bandyopadhyay, a man of letters. He offered us to write with him the manuscript of this publication entitled Biochemical, Immunological and Epidemiological Analysis of Parasitic Diseases.

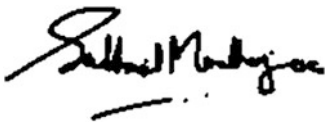
Dr. Nitisranjan Das is lucky to have his valuable and meaningful friendship. Dr. Amit Chattopadhyay is proud to have him as his Ph.D. supervisor. Both of us dedicate this volume to the memory of our great friend and mentor Late Professor Dr. P.K. Bandyopadhyay who had a dream to write such a book.

Foreword

It is my utmost pleasure to dedicate the book on parasitology to the student and the scientific community. As a former undergraduate student of zoology at Calcutta University, I always looked out for a decent reference/textbook for each subject matter covered under the curriculum. I can confidently say that this book will definitely fill the gap in the subject matter of parasitology. Not only that, but it will also serve as a text/reference book for a more advanced postgraduate programme covering parasitology. Needless to add, this book is a comprehensive quencher for those who seek first-hand knowledge in parasitology.

The three authors of this book have vast experience in parasitology, and I would like to appreciate their hard work and thoughts to bring out this enlightenment in the field of parasitology. I wish them success in their great endeavour.

(I would like to declare that all the opinions expressed here are my own and has no bearing with my employer/sponsor.)



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Suddhasil Mookherjee

Preface

This textbook is written specially for students who are engaged in higher studies on parasitology. It comprises the history of discovery, geographical distribution, habitat, morphology, life cycle, energy production, pathogenesis and diagnosis of each and every parasite described. Host defence mechanisms, i.e. immune response by the host, are also included. It is seen that these topics are most important to the majority of students.

Parasites of the phylum Protozoa, Nemathelminthes, Platyhelminthes and Arthropoda are included in this edition. The edition integrates a precious wealth of information on epidemiology, biochemistry, molecular biology, physiology and nutrition, immunology, ecology and evolution of the parasites, so students will have the urge to study the fascinating world of parasites. Updated information on the prevalence of infections is also included in this book. The study of parasitology is very important from the point of human diseases as the parasites residing in our body cause disturbances to the normal physiology of us leading to pathological conditions. The parasites are dangerous relatives rather than villain of the human society.

The subject parasitology attracted attention during World War II and several years thereafter due to belated realizations of the importance of the subject as a factor in world health as well as in the welfare of the military personnel. The rapid advances in knowledge in the field of parasitology made it necessary to revise and take the help of different branches of life sciences to control the parasitic diseases. We have made a conscious effort to lay more stress on zoological and physiological aspects of parasitology. However systematic classification is not neglected but has been included at the end of appropriate chapters. The method of laboratory diagnosis of parasites is of paramount importance as only clinical symptoms of the diseases are not always sufficient for the detection of the causative agent of the disease. We have tried our best to give a broader perspective of the science of parasitology. Here Dr. Das records the help of Mrs Ruby Das, M.A., B.Ed., Diploma in Russian Language, in the composition of the manuscript of Dr. Das's contributed chapters. Dr. Das is really indebted to her for her service. Dr. Das and Dr. Chattopadhyay would like to express their sincere gratitude to Dr. Vansanglura, Principal, Serampore College, for his encouragement of this work.

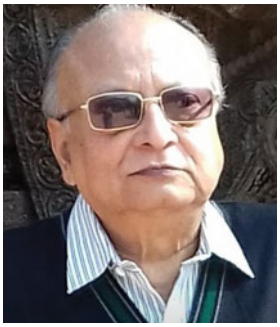
About the Book

This volume pertaining to the disease causing organisms that changes the normal physiology of human beings leading to mortality which contributes the loss of labour force and man-days. The end result is the retardation of economic growth and lack of development of the country. All the advancement and unique discovery in the field of parasitology are presented here to understand the relationship and their detrimental effect not only on individuals but also on the economics of the country itself. Efforts have been made by the authors to cover all aspects of the age-old conflict between parasites and their hosts. The history and mystery of the life-threatening diseases of global concern have found places in this book. The different types of animal associations and host-parasite relationships along with the classification of the parasites are included in the book. Evolution of the parasitism and types of parasites and hosts are presented with the ecology of parasites; parasites from different phylum like Protozoa, Nemathelminthes, Platyhelminthes and Arthropoda are also discussed in the light of modern knowledge. The history of discovery, morphology, life history and pathogenicity of each and every parasite have been discussed with necessary details in a methodical way so that students and readers will not have to search for the required information in an ocean of unnecessary details. One of the most important aspects of parasitology is the vector and their role in transmission of a number of diseases which are still nightmares even in the era of modern science. So vector biology has also been incorporated in this book. Zoonosis, the most attractive and debatable subject of today, has been given its due honour in this book. Parasites of veterinary importance are also discussed for the benefit of veterinary students. We have also tried our best to discuss all the considerable aspects of parasitic nematodes of crop plants to have focused knowledge for agriculture students also. Last but not the least, host-parasite interactions, immune response and biochemical adaptations of parasites which are discovered by the effort of research workers provided the weapon to fight against disease causing organisms, which are highlighted here with all conceivable effort to have a relatively disease-free society and for the benefit of medical students. Modern knowledge and recent information are being incorporated in all the chapters mentioned in the contents. Now it is up to the reader to assess our shortcomings. As a whole this book offers a comprehensive survey of the knowledge on parasitology in lucid and understandable English with diagrams.

Contents

About the Authors

P. K. Bandyopadhyay was a professor in the Department of Zoology, University of Kalyani. He was a nominated member of the National Academy of Sciences, India, and was an executive and life member of the Indian Society for Parasitology. He was an adjudicatory person and was a board member of several universities and colleges in India and abroad. Professor Bandyopadhyay's latest research pertained to fish diseases and their plant-based control measures. He and his team isolated and characterized the bioactive compound, oleic acid, from Carica papaya seed and used the product as aqua-soluble drug in treating fish bacterial disease invivo. He had published more than 170 research articles on animal taxonomy.



N. R. Das is a guest professor in the postgraduate section of Serampore College, Serampore, West Bengal, India. He graduated and completed his Ph.D. from the University of Calcutta as a "Presidencian" under the guidance of Late Dr. H. N. Ray. He has worked as an assistant research officer with the Indian Council of Medical Research, New Delhi, from 1965 to 1970 at Presidency College, Calcutta, before he moved to Serampore College in 1970 as a lecturer. He became head of the department in 1995 as a reader and retired in 2001. Dr. Das was elected to the board of management of the Serampore College in 1998 and served the college as the bursar. He has been bestowed a number of special honors and has availed distinction from different organizations and institutions. Dr. Das is a fellow of the Zoological Society of India and the Royal Society of Tropical Medicine and Hygiene, London. He was also a resource person of the National Council of Educational Research and Training, New Delhi, India, for

more than ten years. He has written a number of reference books on parasitology, wild life, embryology and treatment of tropical diseases published from Calcutta, West Germany, London and Poland.

Amit Chattopadhyay is an assistant professor in the Department of Zoology for UG and PG studies at Serampore College. He has completed M.Sc.in zoology and Ph.D. in the molecular basis of vector biology. Dr. Chattopadhyay joined the Serampore College in the year 2009 and served as head of the Department of zoology. Presently, he is the PG course coordinator for the Department of Zoology. He has been conferred with the Young Scientist of the Year 2016 award by the International Foundation for Environment and Ecology and Confederation of Indian Universities, New Delhi. He has written three books in regional language for undergraduate students of Zoology under University of Calcutta. Dr. Chattopadhyay is a life member of the Indian Society for Parasitology.

Introduction

1

Parasitology is a branch of Zoology as well as a part of the medical science also. The science of parasitology has a long history and has its foundations in zoology with its importance on identification, classification and the interpretation of lifecycles with their concern for the disease caused by parasites. Parasites are those organisms which cannot sustain without the help of others. They are dependent on others for food and shelter but the relation is heterospecific. The organisms which give them food and shelter are hosts. Once entered within the host, parasites take complete control on its host and establish an intimate relationship between them. Parasites establish combinations of physiological, biochemical and nutritional adaptations to set up themselves within the host. Parasites also create mechanism for evading the immune responses of the host so that they can reside permanently within the host until death without any resistance. Parasites are threat to the millions of human and animals throughout the world. They are the reason of human misery and immense income loss to the country. There are innumerable numbers of parasitic organisms in the globe. It is believed that the number and type of parasites are far more than non-parasitic organisms. Viruses and bacteria are not included though these are all parasites yet the number of parasites are far more than those of non-parasitic free living organisms.

The first text book on parasitology was entirely written on zoological aspect. Then a number of text books were written with the advancement of knowledge on parasites about the disease caused by them. Now different aspects of biochemistry, physiology, immunology and epidemiology have been incorporated which are the results of modern research on them.

The parasites are causative agents of different types of diseases of human beings and domestic animals. The evolution of parasitic way of life is so successful that they evolved independently in every phylum of animals and in many plant groups. The life and activity of a number of parasites of different groups are recorded here with their significance in relation to human beings.

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The study of the lifecycle of parasites is most important as the parasites for their maintenance of own species must have to transfer their offspring to a new host. The unique way of transfer, different in different species, is known as infection. All the parasites do not complete their lifecycle within a single host, a large number require two or three different hosts to complete their lifecycle. But each and every time they have to face environmental stress or hazards for safe transfer of their offspring to a new host.

The detailed study of the lifecycle of each and every parasite is necessary to understand the way of infection of them responsible for the particular disease they create or carry. Study of ecology and parasitic adaptations also has great importance from the point of human diseases they create or carry. Not only the lifecycle, parasitic adaptations and ecology, the laboratory diagnosis and recognition are of paramount importance because only symptoms of the diseases are not sufficient to detect the causative agent of the disease.

When the routine process in laboratory is failed to detect the organism, then antigen–antibody reaction is the last hope. Recognition of parasites by laboratory diagnosis, will give us the idea of preventives and treatment of the disease. The study of the host–parasite interaction of different parasites will also indicate the mischievous character of the parasites and will open the path for better recognition of the parasites and their hidden activity.

The study of the metabolism of the parasites will give us the idea of symptoms of the diseases and the detrimental effects on the hosts due to the presence of the different metabolic by-products produced by the parasites.

The antigen–antibody reaction helps us to identify the parasite and gives us the idea of the preparation of the vaccines.

The understanding of infective form of the parasite is very important to prevent the particular disease. The age old conflict between the host and parasites is now making the parasites cleverer and they try their best to establish themselves within the host hiding their identity. The antigen detection is now the most modern method to detect those resistant species.

If we cannot recognize them and prevent infection ultimately we have to suffer and face death. The death of the host does not interfere with the life and maintenance of the parasites as in the meantime the parasites will find newer way to establish themselves in another healthy host. In the eternal conflict between parasites and hosts the immune competent host ultimately becomes victorious and prevents the parasite from invasion and infection. But immune compromised host surrenders before the parasites and allows their way for invasion and infection to host.

The parasites during their transfer of offspring to new host face tremendous environmental stress and hazards but this is mandatory, so mother produces offspring in astronomical figure so that at least some will ultimately find their permanent address through thick and thin though most of them go to oblivion. This will save the species from its extinction.

Here in this book we first attempt to restrict ourselves on the classical aspects of parasitology like classification, systematic, lifecycles and diseases caused by them, then we will try to enter into the modern concept by elucidating aspects of

biochemistry, molecular biology, physiology, immunology and epidemiology based on the knowledge of modern researches.

1.1 General Concept on Parasitism, Parasites and Host

The word parasitism is a type of interspecific relation in which one small individual of a species sustains at the expense of the other individual of another species comparatively large one for food and shelter to the parasite.

Parasites are those organisms which cannot live free without the help of other organism of different species. The small dependent individual is called parasite and the other large individual upon which parasites depend is called host. Due to parasitism the parasite is benefitted at the expense of the host and the presence of parasite creates detrimental effect on the host.

1.1.1 Different Interspecific Relation

The interspecific co-action is interaction between the organisms of two different species, a relation is formed by which both the species may be benefitted or one may benefit at the cost of the other or relation may be neutral where none is benefitted or causes any harmful effect on the other.

The interspecific coactions may be of different types like parasitism, symbiosis, commensalism, ammensalism predation, neutralism, etc. Due to this co-action the density of any one species may increase or decrease which maintains ecological balance of the nature.

1.1.2 Classification of Parasites

The association may be of different types and accordingly is called ectoparasite and endoparasite.

1. The parasites that remain on the body surface of the hosts are called ectoparasites. Example: ticks, mites, lice, etc.
2. The parasites that remain inside the body of the host in different organs or systems are called endoparasites. Example: *Ascaris*.

They may live in the body cavity, within the alimentary canal, in the blood or lymph vessels, within blood corpuscles or in various types of tissues.

Depending on the sites they reside, the parasites are called:

(a) *Haemoparasite:* The parasites living in the blood. Example: *Plasmodium*, *Trypanosoma,* etc.
(b) *Histoparasites:* The parasites that live in the tissues. Example: *Leishmania*.

(c) *Coeloparasites:* The parasites living in the body cavity or coelom of the host are called coeloparasite. Example: *Monocystis*.
(d) *Cellular parasites:* The parasites that reside within the cell as intracellular parasites are called cellular parasites. Example: Trophozoites of *Plasmodium* within the RBC of human beings.

1.1.2.1 Depending Upon the Time Span

Obligatory parasite: The parasites that cannot live independently in any time or throughout their lifecycle are called obligatory parasites. Example: *Taenia*, *Monocystis*, etc.

Facultative parasite: The organisms that are not dependent on others for their existence and can live independently, but sometimes in congenial circumstances act as parasite temporarily are called facultative parasites. Example: Bedbug, Leech, etc.

1.1.2.2 Others

Erratic parasite: Some parasites sometimes migrate to the unusual organs of the hosts and are called erratic parasites.

Sporadic parasite: Some parasites sometimes come closer to the host for collecting metabolic materials and they are called sporadic parasites.

Incidental or accidental parasite: The organisms which sometimes suddenly become parasitized to unnatural host are called incidental parasites.

Pathogenic parasite: The parasites that cause disease in the body of the hosts are called pathogenic parasites.

Hyperparasitism: When a parasite depends upon other parasite for their food and shelter they are called hyper parasites.

Example: Protozoan parasite *Nosema dollfusi* is parasitic on the eggs of Trematode parasite *Bucephalus cuculus*. On the other side *B. cuculus* is parasite on American snails.

1.1.3 Parasitoid

Some Dipteran and Hymenopteran flies lay eggs on the eggs and larva of another fly. The larvae after hatching from these eggs start eating their larva or eggs on which they are deposited. As a result if the hostfly dies the parasites remain alive. This phenomenon is known as parasitoidism and the benefitted species is called Parasitoid.

1.1.3.1 Brood Parasitism

The cuckoos cannot prepare their nest and at the same time cannot incubate their eggs to hatch. They enter into the nests of the crows stealthily and lay eggs there. The crow cannot recognize the eggs of cuckoo and so incubate to hatch them thinking that the eggs are their own. This is called Brood parasitism. Example: Cuckoo.

1.1.3.2 Social Parasitism

When a species exploit another species for their own benefit causing no harm to the other, the relation is called social parasitism.

The Cowbird of North America will not prepare their own nests and will not incubate their own eggs. But they incubate eggs and nurse the nestlings of surrogate father and mother.

General characters of Parasites:

1. The parasites and host must be of two different species.
2. Generally hosts are larger in size than the parasites.
3. Ideal parasites never cause that much harm to the host so that the host may die. Though the heavy infection by parasites and for secondary infection sometimes hosts may die.
4. The length of life of parasites is very much limited but the reproduction rate is very high.
5. There is always a balance of population between the parasites and hosts.
6. One parasite during his lifetime or lifecycle may remain within several hosts.
7. Parasitism may be partial or whole time.
8. The organs of parasites are highly specialized in relation to the parasitic adaptation within the hosts.
9. Most of the time parasites choose a particular place for their habitat.
10. Besides animal plants may also be parasitized.

1.1.4 Parasitic Adaptations

To cope with the microenvironment of host the parasites undergo changes in their structural, physiological characters and reproductional behaviour.

The features are:

Structural adaptations

1. Ectoparasites develop piercing and sucking mouth parts, while the endoparasites develop suckers, hooks, etc. for anchorage to the body of the host.
2. In the parasites sense organs, nervous system, alimentary system, etc. and organs of locomotion are ill developed or sometime absent.
3. To suck blood from the host or to suck cell sap from plants parasites develop sucking and boring apparatus.
4. Parasites living in the intestine of a host have an envelope of cuticle over them so that they will not be digested by the digestive enzymes of the host.

Physiological adaptations

1. Parasites those who suck blood from the body of the host have anticoagulant in their salivary secretion to prevent coagulation of blood during sucking.
2. Endoparasites exhibit anaerobic respiration.

3. Parasites are transferred from one host to other by ingestion of the eggs, cysts, etc. through food and drinks or by vectors. The route of infection is called faecal–oral route.

Reproductive adaptations

1. Parasites show high rate of reproduction, parthenogenesis, hermaphroditism polyembryony, intermediate hosts and complicated lifecycle.

1.1.5 Host

The hosts are those within whom the parasites live and grow.

1.1.6 Classification of Hosts

Definitive or final host: The hosts in which parasites undergo their sexual cycle are called final or definitive host.

Intermediate host: The hosts where parasites undergo asexual lifecycle are called intermediate hosts.

Paratenic host: To complete the lifecycle some parasites enter into some organisms, those are not usually their host but use the organisms to reach their final host, they are called paratenic hosts.

Reservoir host: Some animals store in their body a part of the lifecycle of some parasites and spread from there to another hosts are called reservoir hosts.

1.2 Need of the Study of Parasitology and Its Present Relevance

The study of parasitology is very much important because the parasites are disease causing organisms which change the normal physiology of human beings leading to morbidity and mortality that contributes diminished work capacity of human beings resulting into the loss of labour force and workers. The ultimate result is the retardation of economic growth and development of the country. Out of the all relations among non-sexual individuals parasitism is the worst and result of this queer relation is against the well being of the human society.

The parasitic infections occur throughout the world. But they are very common in third world, tropical and subtropical countries where the climate is congenial to the life and spread of parasitic infections. Besides, other reasons are there for high rate of parasitic infections. These are high population density, poor condition of sanitation, poor personal hygiene, extreme poverty, living in slums, ignorance and lack of community medical service.

Recently with all these factors some added reasons are deforestation, building of dams which help vector breeding and density of reservoir host. The life style of slum dwellers and poor municipal services greatly contributed to the spread of infections.

To alleviate the lead effects of infective diseases caused by parasites the study of parasites is very much important. All the advancement and unique discovery in the field of parasitology help us to understand the relationship and the detrimental effects of the parasitic infections not only on the individuals but economy of the country itself. Now the parasitologists are trying their best to know the interaction between host and parasites which are being traced up to the cellular and chemical level. The most important aspect of parasitology is the vector and their role in transmission of the diseases which is being pursued by the Parasitologists has helped us in finding the solution of this great problem. All these are opening a new path in the discovery of vaccine and medicine for the critical parasitic diseases.

These are the prime needs for study of the parasitology and the study will lead us one day to create a disease free life of human beings on our planet and hopefully we are marching on to that goal.

Protozoan Parasites

2

The protozoan parasites are known to parasitize both human beings and domesticated animals, thus causing immense loss to human society. These parasites cause different important diseases like malaria, Chagas disease, sleeping sickness, kala-azar, leishmaniasis, etc. those are major diseases of tropical countries bringing death to human beings and their domesticated animals.

In this chapter the flagellates like *Trichomonas vaginalis*, *Giardia intestinalis*, *Trichomonas hominis*, *Trypanosoma cruzi*, *Trypanosoma gambiense*, *Leishmania donovani* are discussed about their history of discovery, habit and habitat, morphology, modes of infection, life cycle, pathogenesis, energy production, diagnosis, epidemiology of the parasites and immune response of the host.

Parasitic amoebae like *Entamoeba histolytica*, *Acanthamoeba*, *Naegleria fowleri*, *Entamoeba coli*, *Dientamoeba fragilis*, *Iodamoeba butschlii* are described concerning their same factors as the parasitic flagellates.

Coccidia like *Cryptosporidium parvum*, four species of malarial parasites, *Toxoplasma gondii*, *Babesia* and an intestinal *ciliophoran*, *Balantidium coli* causing diseases like dysentery are also discussed under the same subheadings.

Systematics of all these protozoan parasites are written for the benefit of the students who are interested in the classification of these parasites to know their exact position in the animal kingdom.

Protozoa is the subkingdom under Kingdom Animalia. This scheme of classification is introduced by N.D. Levine in the year 1980. Before that Protozoa was regarded as a phylum in the scheme of classification by T.J. Parker and W.A. Haswell in 1940. In the year 1942 A.J. Marshall and W.D. Williams edited a book where Parker and Haswell's classification was accepted and described.

In the year 1675 Antony Van Leewenhoek found for the first time the microscopic, single celled organisms and described them. In the year 1818 Scientist Goldfuss for the first time coined the term Protozoa for this group of organisms. After the discovery of cell by Robert Hooke in the year 1839, Van Siebold in 1845

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understanding the characteristics of Protista and on the basis of this discovery he for the first time applied the name Protozoa for the microscopic unicellular organisms.

N.D. Levine in the year 1980 divided the subkingdom Protozoa into seven phyla. Out of these seven phyla the phylum Sarcomastigophora, phylum Apicomplexa, phylum Microspora, phylum Ascetospora, phylum Ciliophora contain parasitic organisms. Examples are in phylum Sarcomastigophora organisms like Giardia, Trypanosoma, Amoeba, etc. are parasites. In phylum Apicomplexa organisms like Gregarina, Monocystis, Plasmodium, Toxoplasma, etc. are the parasitic animals. In the phylum Microspora all the members of the phylum are endoparasites. The members of the phylum Ascetospora are parasites. In phylum ciliophora very few are parasitic organisms.

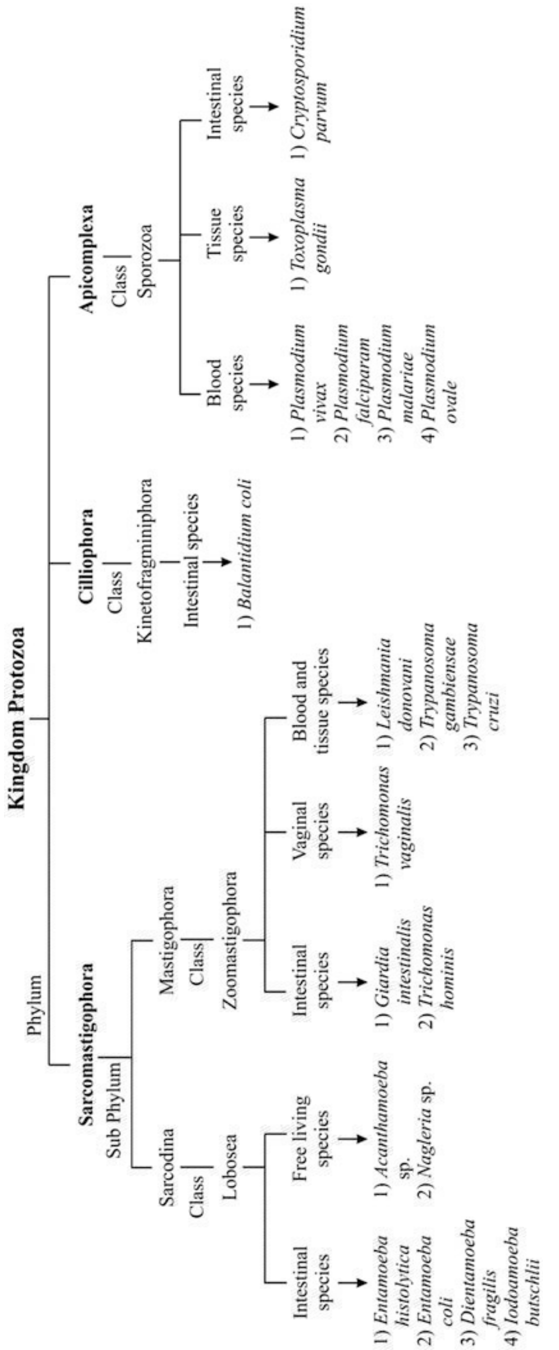
The Protozoa are unicellular organisms and the single cell performs all the vital functions of life. As protozoans are very very small they can be studied only under microscope. The main structure of any member of the parasitic Protozoa consists of protoplasm enclosed in a cell membrane, plasmalemma. The protoplasm is divided into cytoplasm and nucleus. Though parasites some have the power of movement. The movement is performed by either pseudopodia or cilia or flagella, etc.

Some of the protozoan parasites are:

Entamoeba histolytica	*Plasmodium falciparum*
Giardia intestinalis	*Toxoplasma gondii*
Trichomonas vaginalis	*Cryptosporidium parvum*
Balantidium coli	*Babesia bigemina*
Trypanosoma cruzi	
Trypanosoma brucei	
Leishmania donovani	
Plasmodium vivax	
All are infective to human beings	

The Phylum Protozoa though it is now called kingdom Protozoa as per the classification of N.D. Levine (1980) have more than 45,000 species of which 10,000 are parasitic in invertebrates and in all species of vertebrates. Human and their domesticated animals serve as the hosts of the protozoan parasites like malaria, Chagas disease, sleeping sickness, Leishmaniasis, etc. those are considered major diseases of the third world tropical countries. In poultry, dairy and domesticated animals theileriosis and coccidiosis present a continuous threat to the persons who are in these business and trying to produce food for human beings.

In the living world kingdom Protozoa have three Phyla under which there are a number of parasites those attack human beings and domesticated animals. They are:


Kingdom Protozoa
Phylum
Sarcomastigophora
Sub Phylum
Sarcodina
Class
Lobosea
Intestinal species
1) Entamoeba histolytica
2) Entamoeba coli
3) Dientamoeba fragilis
4) Iodoamoeba butschlii
Free living species
1) Acanthamoeba sp.
2) Nagleria sp.
Mastigophora
Class
Zoomastigophora
Intestinal species
1) Giardia intestinalis
2) Trichomonas hominis
Vaginal species
1) Trichomonas vaginalis
Blood and tissue species
1) Leishmania donovani
2) Trypanosoma gambiensae
3) Trypanosoma cruzi
Cilliophora
Class
Kinetofragminiphora
Intestinal species
1) Balantidium coli
Apicomplexa
Class
Sporozoa
Blood species
1) Plasmodium vivax
2) Plasmodium falciparam
3) Plasmodium malariae
4) Plasmodium ovale
Tissue species
1) Toxoplasma gondii
Intestinal species
1) Cryptosporidium parvum

2.1 Flagellates

2.1.1 *Trichomonas vaginalis*

Trichomonas vaginalis is largest in size among the Trichomonads in human beings.

2.1.1.1 History of Discovery

This parasite was first discovered by Donne in 1836 in vaginal secretion. Next year he called this parasite *Trichomonas vaginalis*. He created the genus Trichomonas.

Geographical distribution: It is a common vaginal flagellate protozoan parasite distributed throughout the world. It is prevalent in Negro women twice as high as white women. *T. vaginalis* is also found in man occasionally though it is a parasite of women particularly. The disease caused by it is known as vaginitis. *Trichomonas vaginalis* is also found in man in the urine or in prostate secretion after prostatic massage.

2.1.1.2 Morphology

It is pear shaped, length varies from 10 to 30 μ but in average 20 μ long and 5–10 μ in breadth. This protozoan flagellate exists in trophozoite stage only, like other flagellates they do not form cysts. The trophozoites have five flagella (Fig. 2.1). Four of them are anterior flagella and one posterior. The posterior one remains along the margin of the undulating membrane which does not extend beyond the middle of

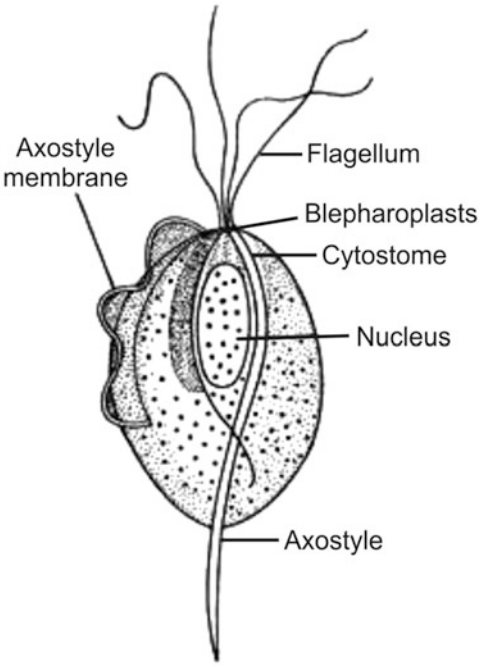


Fig. 2.1 *Trichomonas vaginalis*

the body. The body is supported by a stiff axostyle that originates from the anterior end and projects posterior beyond the body like a tail spine. The undulating membrane is attached to the body by a flexible rod known as costa. The projected axostyle is at posterior end and the organism seen to anchor themselves to the debris by this structure. The nucleus is oval in shape and is formed of scanty scattered chromatin granules. In the cytoplasm of the body some deep staining granules are seen and they are also found in rows along the costa known as metachromatic granules. The cytostome or cell mouth is not very distinct and the cell contains few food vacuoles. Beside the nucleus there is a structure called parabasal apparatus which is sausage shaped and light stained body. There is also a deep staining fibril that extends up to the middle of the body is the parabasal fibril.

The fresh active trophozoites exhibit jerky movements.

2.1.1.3 Habitat

T. vaginalis is primarily a parasite of vagina of women, it also invades the Skene's gland in urethra. In males they are found in urethra and prostate. *T. vaginalis* found in abundance in the upper part of the vagina up to the cervix of the uterus but do not enter into the uterus.

Scientists have found that *T. vaginalis* is associated with a low acidic creamy white frothy discharge.

2.1.1.4 Modes of Infection

T. vaginalis infection is accompanied by low acidity of the vagina, thin epithelium and less glycogen content in the cells. Normally the pH of the vaginal passage is highly acidic which prevents the infection. It is found that in children the vaginal passage is not highly acidic. The trophozoites of *T. vaginalis* are resistant to environmental changes. They may survive in urine and damp towel for a considerable period. These help in the spread of infection. Living trophozoites are seen on wet under cloths even after 24 h. *T. vaginalis* may infect the foetus during passing through the birth canal of the infected mother.

The trophozoites multiply by binary fission. The parasite is transmitted by sexual contact and also by sharing of towels or undergarments.

2.1.1.5 Life Cycle

The trophozoites are infective forms. It resides in vaginal passage, bartholin gland and the urethra of women and urethra, prostrate, seminal vesicles and epididymis in man. The multiplication of the trophozoites takes place by binary fission. The parasite is transmitted by sexual contact and also by sharing of towels or undergarments.

They cause vaginitis after an incubation period of about a month.

2.1.1.6 Pathogenicity

They cause vaginitis after an incubation period of about 1 month. The symptoms of vaginitis by *T. vaginalis* are a yellow frothy bad odorous discharge. The infection is also associated with leucorrhoeic condition. The vulva region becomes very much

red due to congestion of capillaries, feeling of itching, painful micturition, tendency of frequent micturition and painful coitus also occur. In males the infection is asymptomatic but spreads the infection to female sexual partner during coitus.

2.1.1.7 Energy Production

Trichomonads are aerobic organisms. They acquire energy from incomplete degradation of simple sugars producing lactic acids and acetic acids. (see *Trichomonas hominis*).

In in vitro culture, it is found that these organisms grow most successfully in glucose and maltose.

ATP is formed in the cytoplasm by substrate level phosphorylation which is used by the organisms and energy is liberated from ATPs.

2.1.1.8 Diagnosis

In females *T. vaginalis* is found in sedimental urine, vaginal secretion swab but in males in the urine or in prostatic secretion after prostatic massage.

2.1.1.9 Prophylaxis

Male and female sexual partners are treated simultaneously. Its control and prevention needs time and patience.

2.2 Intestinal Flagellates

2.2.1 *Giardia intestinalis*

2.2.1.1 History of Discovery

The flagellate parasite was first seen by Leeuwenhoek in 1681 while examining his own stool. Author (Das) separated for the first time the *Giardia* in Indian Goats and Lions (Das and Jha 1967; Jha et al. 1968).

2.2.1.2 Geographical Distribution

These flagellate parasites are cosmopolitan in distribution.

2.2.1.3 Habit and Habitat

Giardia is a parasite of human beings and found in the duodenum and other parts of small intestine. Sometimes they are found in the colon and bile duct.

2.2.1.4 Structure

Giardia occurs in two different forms: Trophozoite and cyst.

Trophozoite

The body is bilaterally symmetrical and measures 10–18 μ in length. The shape of the body is like 'tear drop'. The dorsal surface is convex and ventral surface is concave. The concave ventral surface has two rigid bilobed concave adhesive discs.

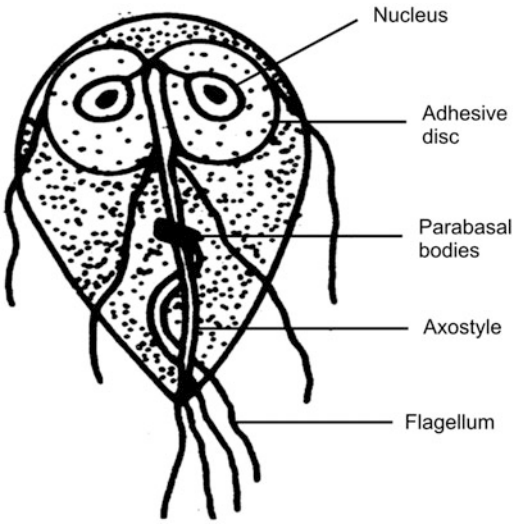


Fig. 2.2 Trophozoite of *Giardia intestinalis* (*Advanced Parasitology*, Das)

These two ventral discs occupy most of the anterior part on the ventral surface of the trophozoites. These adhesive discs are organelle of attachment which make contact and attach the parasite with intestinal wall of the host (Fig. 2.2). The attachment is also achieved by a hydrodynamic force generated by a pair of ventral flagella and a mechanical force developed by contractile protein like giardin present in the ventral disc (Karyakarta and Damle 2003).

Just below the adhesive discs there is a single sometimes double median bodies which stain black in iron-alum-haematoxylene. There are four pairs of flagella: anterior, posterior, ventral and caudal pair.

There are two nuclei placed at the broader end of the body containing haploid number of chromosomes. A single or double axostyle (Kinetosome) is seen in the mid ventral line of the body.

Giardia is unable to synthesize phospholipids and sterols which are necessary for its growth and metabolism. They use phospholipids and sterols found in the intestine of the host. It is proved that bile salts present in the intestine facilitate the entry of these organic chemicals within the trophozoites.

Cysts

The fully formed cyst is oval in shape and measures 12 μm × 7 μm in dimension. The cyst wall is thin and cytoplasm does not fill the entire cyst. There are four nuclei which remain clustered at one end or lie in pairs at opposite poles. The remains of disintegrated flagella are seen as streak in iodine preparation. The axostyle lies diagonally.

2.2.1.5 Life Cycle

Mature cysts are the infective forms, the normal dose is 10–100 cysts. The transmission route is faecal–oral. Excystation happens in small intestine of the host. The