MEDICAL PARASITOLOGY

A SELF-INSTRUCTIONAL TEXT

SEVENTH EDITION

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DEDICATION

To my family: Anita, Sheryl, David, Elaine, Talia, and Alex
To teachers and scientists everywhere, preparing the next generation

—Ruth Leventhal

To my dear wife and best friend, Cathy, and my daughter Valerie

—Russell F. Cheadle

PREFACE TO THE FIRST EDITION

There are many available textbooks about parasitology. Some of these treat the biology of parasites in great depth, while others are more graphic in nature. The laboratorian or clinician needs both kinds. This book was designed to provide a concise description of the biology and epidemiology of human parasites, coupled with an extensive series of color photographs and line drawings to facilitate visual recognition of parasites found in clinical specimens. Furthermore, several modes of graphic presentation have been incorporated in order to aid the various approaches to learning and mastering the requisites.

This book resulted from our recognition of the need for a self-instructional text in parasitology. Present formal course instruction in medical parasitology is often limited and generally is not designed to allow for different learning styles. Russell Cheadle conceptualized and wrote the original draft of this self-instructional text, while the research and writing thereafter became a truly collaborative effort. This product is, we believe, a useful learning tool for students in biology, medical technology, medicine, and public health, as well as an effective pictorial reference book for the clinical laboratory.

We wish to thank Catherine Cheadle, Mary Stevens, and Valerie Fortune for their kind assistance. Russell Cheadle would also like to thank Dr. Herbert W. Cox, his graduate advisor, for his encouragement.

Ruth Leventhal
Russell E. Cheadle

PREFACE TO THE SEVENTH EDITION

Since the publication of the first edition of this text in 1979, various phenomena have increased the incidence of parasitic diseases among North Americans. Increased world travel by U.S. residents and the influx of immigrants from underdeveloped regions have brought increasing numbers of once seldom-encountered parasites into this country. Shifts in sexual behaviors in our society have altered the traditionally accepted epidemiology of infections such as giardiasis and amebiasis. In addition, individuals with acquired immunodeficiency syndrome (AIDS) have contracted infections caused by previously rare opportunistic parasites and have suffered more severe symptoms from infections caused by usually less virulent organisms. Such situations lend an increased urgency to correctly diagnose and treat parasitic diseases by U.S. physicians and to detect these diseases by laboratory technologists. On a global basis, parasitic infections remain a most serious consideration. They affect the morbidity and mortality levels in every nation, affecting countries with tropical and temperate climates very significantly; therefore, now more than ever, all health professionals need a fundamental understanding of the diagnosis, treatment, and prevention of parasitic diseases. These ideas have guided this edition's revision. *Medical Parasitology* is designed to provide the reader with a concise, systematic introduction to the biology and epidemiology of human parasitic diseases. The text is supported throughout by an array of carefully coordinated graphics. Many of the changes incorporated in this revision are based on responses from surveys of the users of the previous editions. The presentation of the symptomatology, pathology, and treatment of each parasitic disease has been expanded. New parasites have been added, and most notable is the reorganization of the sixth edition's Chapter 5, which is now divided into four shorter chapters that separately cover each of the major protozoan groups. Information concerning the role of arthropods as ectoparasites has been enhanced, and new color photographs have been added to provide greater clarity of these parasites. Coverage of serologic testing has been strengthened. Resource lists for general and immunologic supplies have been added as a separate appendix. Epidemiology and treatment topics have been reorganized and are expanded in the final chapter.

Enhancements to the graphic elements of the text have not been neglected. Line drawings and full-color photographs of newly added parasites are included and previous drawings modified as necessary. Other new photographs enable students to compare more actual images with our line drawings. All laboratory procedures were updated and expanded to conform to current quality control standards. The complete review Atlas remains in the text as well. Additionally, an extensive group of slides covering common artifacts seen in laboratory specimens has been added to the Atlas. The inside covers provide comparative charts illustrating parasitic forms for use as a quick reference tool while screening specimen materials. Review questions within the text, end-of-chapter post-tests, new case studies, and thoroughly updated bibliographies provide other useful learning resources. Instructor's Resources are available to adopting educators via Davis*Plus* (davisplus.com). These online resources include a bank of 120 test questions, PowerPoint presentations with lecture points, and a searchable Image Ancillary. Also available at Davis*Plus* are interactive student exercises that include additional case studies, flash cards, word puzzles, and an audio pronunciation key for all named parasites, all of which are easily accessible to students and instructors. These changes will dramatically enhance each student's learning experience.

Russell F. Cheadle

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Lynne S. Garcia for generously permitting the use of new color photographs in the Atlas and in Chapters 8 and 9; Dean DeChambeau, our developmental editor for his creative ideas and diligent attention to detail and to all of the other dedicated support staff for helping to smooth out the bumps; and Catherine Cheadle for her help and support throughout this process.

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CHAPTER 1

Introduction

LEARNING OBJECTIVES FOR CHAPTER ONE

On completion of this chapter, you will be able to:

1. Understand the organizational features of this text.
2. Correctly define the terms listed in the chapter glossary.
3. Draw, correctly label, and explain each of the five parts of a typical parasite life cycle.
4. List the six essential details needed to identify a parasite and its related disease.

GLOSSARY

accidental (or incidental) host. Infection of a host other than the normal host species. A parasite may or may not continue full development in an accidental host.

apical complex. Polar complex of secretory organelles in sporozoan protozoa.

carrier. A host harboring a parasite but exhibiting no clinical signs or symptoms.

commensalism. The association of two different species of organisms in which one partner is benefited and the other is neither benefited nor injured.

diagnostic stage. A developmental stage of a pathogenic organism that can be detected in human body secretions, discharges, feces, blood, or tissue by chemical means or microscopic observations. Identification serves as an aid in diagnosis.

definitive host. The animal in which a parasite passes its adult existence, sexual reproductive phase, or both.

differential diagnosis. The clinical comparison of different diseases that exhibit similar symptoms; designed to determine which disease the patient has.

disease. A definite morbid process having a characteristic train of symptoms.

ectoparasite. A parasite established on or in the body surface of its host.

endoparasite. A parasite established within the body of its host.

epidemiology. A field of science dealing with the relationships of the various factors that determine the frequency and distribution of an infectious process or disease in a community.

facultative parasite. An organism capable of living an independent or a parasitic existence; not an obligatory parasite, but potentially parasitic.

generic name (or scientific name). The name given to an organism consisting of its appropriate genus and species title.

genus (pl. genera). A taxonomic category subordinate to family (and tribe) and superior to species, grouping those organisms that are alike in broad features but different in detail.

host. The species of animal or plant that harbors a parasite and provides some metabolic resources to the parasitic species.

in vitro. Observable in a test tube or other nonliving system.

in vivo. Within the living body.

infections. Invasions of the body by a pathogenic organism (except arthropods), with accompanying reaction of the host tissues to the presence of the parasite.

infective stage. The stage of the life cycle at which the parasite is capable of entering and continuing development within the host. Required part of the life cycle of that parasite.

infestation. The establishment of arthropods on or within a host (including insects, ticks, and mites).

intermediate host. The animal in which a parasite passes its larval stage or asexual reproduction phase.

life cycle. Entrance into a host, growth, development, reproduction, and subsequent transmission of offspring to a new host.

metazoan. Belonging to a subkingdom of animals consisting of all multicellular animal organisms in which cells are differentiated to form tissue. Includes all animals except protozoa.

mutualism. The association of two different species of organisms in which each individual benefits from the activity of the other. Similar interactions within a species are known as cooperation.

obligatory parasite. A parasite that cannot live apart from its host.

parasitemia. The presence of parasites in the blood (e.g., malaria schizonts in red blood cells).

parasitism. The association of two different species of organisms in which the smaller species lives on or within the other and has a metabolic dependence on the larger host species.

pathogenic. Production of tissue changes or disease.

pathogenicity. The ability to produce pathogenic changes.

reservoir host. An animal that harbors a species of parasite that is also parasitic for humans and from which a human may become infected.

serology. The study of antibody-antigen reactions in vitro, using host serum for study.

species (abbr. spp.). A taxonomic category subordinate to a genus. A species maintains its classification by not interbreeding with other species.

symbiosis. The association of two different species of organisms exhibiting metabolic dependence by their relationship.

transport host. An animal that harbors a parasite that does not reproduce; it carries the parasite from one location to another to infect a new host.

vectors. Any arthropods or other living carriers that transport a pathogenic microorganism from an infected to a noninfected host. A vector may transmit a disease passively (mechanical vector) or may be an essential host in the life cycle of the pathogenic organism (biological vector).

zoonosis (pl. zoonoses). A disease involving a parasite that has accidentally infected a human; the normal host for the parasite is an animal.

HOW TO USE THIS TEXT

To function as a competent practitioner and be prepared to aid in the accurate diagnosis of parasitic infections, you must exhibit knowledge and skills in both clinical and academic areas. This self-study text is designed to help you reach that goal. The following two lists of objectives apply to the whole text. Use these learning objectives as guides for your acquisition of knowledge. Ensure that you have acquired the information necessary to accomplish each learning task described before you attempt each chapter's post-test.

Learning Objectives for This Text

Academic Objectives

On completion of this self-study text, you will be able to:

1. State definitions of the general terms used in parasitology.
2. Recall the scientific and common names for each parasite studied.
3. State the general geographic distribution of each parasite.
4. State the parasitic form that causes disease in humans and its location in the body.
5. Describe the means by which each infection occurs.
6. State the name of the disease produced and its most common symptoms and pathology.
7. State the appropriate body specimen to examine for the diagnostic stage of each parasite, and list other laboratory tests useful in its diagnosis.
8. Recognize and draw the diagnostic stage of each parasite.
9. Demonstrate graphically the life cycle of each parasite.
10. Discuss the procedures used to identify parasites (including concentration, culture, and staining techniques), as well as potential sources of error and quality-control procedures.
11. Identify potentially successful methods for the epidemiological control of parasitism.
12. Given sufficient case history information, identify the most probable helminth or protozoan causing the symptoms and the body specimen of choice for study.

Practical Objectives

On completion of this self-study text and with appropriate experience in the laboratory, you will:

1. Be able to perform appropriate and satisfactory microscopic and macroscopic examination of body specimens—such as blood, urine, or feces—to detect and identify parasites. (*Note:* Acceptable performance is the identification of at least 80% of the parasites present in specimens. In actual clinical settings, accuracy should be 100%.)
2. Have mastered two fecal concentration techniques (one for sedimentation and one for flotation) as demonstrated by satisfactory performance of these techniques and correct identification of recovered parasites.
3. Be able to prepare and stain slides of fecal material and blood satisfactorily as demonstrated by the correct diagnosis of at least 80% of the parasites contained therein.
4. Be able to perform a variety of other tests satisfactorily, including a blood concentration test for microfilaria and serodiagnostic testing for various parasites.

This text is best used in conjunction with a course that includes supplementary hands-on laboratory experiences. By the time you have worked through studying the helminths (which are presented first in the text), your practice with microscopic and other techniques will have made you more effective and efficient in locating and identifying the small protozoa and in differentiating them from other formed, unicellular structures or artifacts present in body specimens.

To prepare you to identify organisms that parasitize humans, Chapters 2 to 9 follow the same format to explain parasitism as a biological concept and introduce specific parasites of medical importance. The chapters also include the information necessary to assist in the diagnosis of infection and the recommended treatments (e.g., drugs or surgery).

Learning objectives at the beginning of each chapter should guide your study. Nine glossaries of important terms are included in this text. In addition to the basic terms defined in the glossary at the beginning of this chapter, separate glossaries are included in the chapters on the Nematoda, Cestoda, Digenea, Protozoa, and Arthropoda. Study and master all of the words in each of the glossaries. Throughout the text you will find words in bold type (e.g., **vector**) that are defined in the glossary of that chapter. It is recommended that the glossaries be used in conjunction with the boldfaced terms appearing in the text; a medical dictionary, however, will be helpful to you in your studies.

The **life cycles** of parasites of major medical importance are displayed graphically and pictorially to help you understand how transmission and the spread of infection can occur and how the location of each parasite stage in the human body correlates with clinical symptoms and pathology. Figure 1-1 is a generalized example of a life cycle that illustrates the key

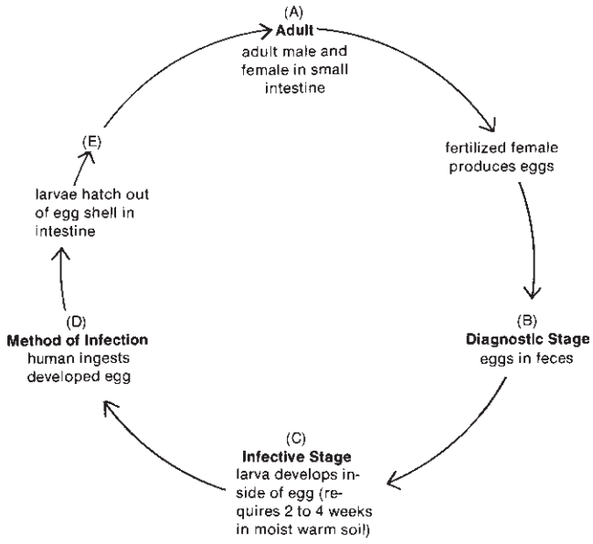


FIGURE 1-1 An example of a life cycle.

points to study while learning about any parasite. Understanding the life cycle is the key to understanding how to break the cycle in nature and thereby control the transmission of parasitic diseases as well as knowing which parasite stage will be seen in body specimens, such as blood, urine, feces, or sputum; this is the key to diagnosis.

Minimally, you must know the five parts of a life cycle noted on Figure 1-1:

1. *Location of the parasite stage in a human host* (e.g., adults in intestinal tract or in tissue site).
2. *The means by which parasite stages leave the human host* (e.g., eggs in feces; feeding insect ingests larval stage from tissue). Usually, the parasite stage that is seen and identified in the laboratory is found when examining a fecal or tissue specimen from an infected human. A parasite stage that is routinely recognized in a biological specimen and thus serves as a key to diagnosis is termed the **diagnostic stage.**
3. *When the parasite is infective.* The parasite stage that is infective to humans (e.g., the third-stage larva) is termed the **infective stage.** To understand how the potential spread of the disease can be halted, you must know if external development is required for the parasite to reach infectivity (e.g., eggs develop in the soil) or if it spends a part of the life cycle in another host.
4. *The means by which a new human host is infected* (e.g., egg is ingested; larvae enter through skin).
5. *Sites of development and maturation of the parasite in humans* (e.g., it migrates through the intestinal wall, liver, and lungs and then is coughed up and swallowed into the intestinal tract).

For a substantive review of the biology of any particular parasite, you are referred to a variety of texts and specific journal articles, as noted in the bibliography of each chapter. The bibliographies include both classic references in the field plus newer findings of importance. Pertinent references have been included in the bibliographies to guide you toward in-depth studies in various areas of parasitology, such as the biochemistry, treatment, pathology, or immunology of parasitic infections.

While learning the text material, be sure to also study the corresponding color photographs with their extensive descriptive key found in the Atlas located at the front of the book. These descriptions and pictures have been chosen carefully to provide important information on each parasite discussed and are arranged in the same sequence as the species presented in the text. Additionally, the Atlas and inside cover charts are useful stand-alone exam review tools and as quick desk references when observing microscopic samples.

Name tables throughout the book list the scientific genus and species names and the common names for the parasites of medical importance. Proper pronunciation of the scientific name is given beneath each name. Practice pronouncing the scientific name aloud and spelling it on paper; correct pronunciation will help you remember the name and relate it to other important information about the particular parasite.

Additional tables in the chapters will help you review the pertinent information for each parasite, including the epidemiology and the major disease manifestations that these parasites cause. Nineteen practice case studies are also found in this text. Answers for the cases are included at the end of the book.

When you complete the study of each organism, you should be able to write:

1. The scientific name
2. The common name
3. The location of the adults in humans
4. The diagnostic stage and body specimen of choice for examination
5. The method of infection of humans
6. Other specific information pertinent to the diagnosis of each parasitic infection

Each chapter contains "For Review" questions that emphasize important points. You should respond in writing to each question. By answering each of the questions, you will be able to test your understanding of the material presented. Check the accuracy of your answers by reviewing the chapter.

Review each chapter and its corresponding plates and plate key until you have successfully completed your learning tasks as outlined in the learning objectives When you think you have mastered the chapter materials, you will be ready to take the brief post-test

following each chapter. The post-test enables you to judge your mastery of that particular area. The directions for each test are included on the test pages, and the answer key begins on page 201.

You must achieve a score of 80% correct to demonstrate minimally satisfactory completion of each chapter, but you are encouraged to review difficult-to-grasp material and use supplementary reading materials if needed, until you are satisfied that you have learned the material completely. A final examination at the end of the text allows you to evaluate your overall self-paced learning accomplishment.

FOR REVIEW

1. Draw, correctly label, and explain each of the five parts of a typical parasite life cycle.
2. List the six essential details needed to identify a parasite and its related disease.

Now let's begin learning about parasites!

THE IMPACT OF PARASITISM

North Americans do not suffer from a multitude of harmful parasites, largely because of general good health; high standards of education, nutrition, and sanitation; a temperate climate; and the absence of necessary **vectors.** Parasitic **infections** do exist in the United States, however, and are still far from eradicated. Increased travel throughout the world and the general low level of understanding about parasitic infections has added to the problem of **disease** transmission in the United States. Many other parts of the world have high levels of parasite-induced morbidity and mortality among humans and animals, as well as significant parasitic damage to crops. These problems place great drains on human resources and food productivity, thus affecting the international economy. In recognizing this problem, the World Health Organization (WHO) named five parasitic diseases (malaria, leishmaniasis, trypanosomiasis, onchocerciasis, and schistosomiasis) as among the six most harmful infective diseases afflicting humanity today. More than 4.5 billion people harbor parasites.

A worldwide survey of common helminth infections was attempted in the 1940s. Global prevalence of *Ascaris lumbricoides,* hookworm, and *Trichuris trichiura* infections at that time were estimated to be 24%, 24%, and 17%, respectively. Similar surveys performed in the early 1990s and again early this century found the same relative percentages for these parasitic infections. When one adds to these numbers that 489 million people have malaria, which kills 1.5 million people each year (including at least 1 million children younger than 5 years of age), it becomes evident that parasitic infections greatly affect the health and welfare of the world's population.

To estimate the true impact of parasitism including lost productivity and quality of life limitations, current researchers measure the disability-adjusted life year (DALY) and use patient-based quality-of-life (QoL) interview techniques to compare the effects of diseases among infected individuals. Various estimates suggest that the global parasitic diseases burden listed in Table 1-1 is around 52 million DALYs, which reflects a huge amount of lost time for millions of infected individuals.

The real significance of these numbers is the realization that at least 25% of the world's population (about 1.9 billion people) suffer from the consequences of parasitic infections, such as malnutrition, iron deficiency anemia, and other parasite-specific chronic health effects, with periodic acute disease symptoms (e.g., malaria). The economic consequences are staggering. Overcoming the effects of parasitic infections requires improvements in water and sewage treatment, changes in behavior due to improved health education, and overall improvement in the economic standards of living. Treatment of infections and prevention of future infections require chemotherapy and future development of vaccines. These are serious challenges, especially in poor countries.

Peter Hotez (2008) has stated, "It is appalling that helminth infections and other NTDs (neglected tropical diseases) are having such a devastating impact on the poor in Sub-Saharan Africa given that we have effective treatments to alleviate their sufferings. For $200 to $400 million a year over five years we could significantly reduce the burden of helminth infections and other NTDs from much of Sub-Saharan Africa. That's a minimal investment with maximum returns." Furthermore, other observations suggest that by reducing the incidence of NTDs, there may also be a significant impact on other diseases such as malaria, schistosomiasis, and human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS) due to individuals' improved health.

Many organizations have worked to treat infected individuals, and others are actively pursuing vaccines. Vaccines for hookworm and schistosomiasis have been developed and are in various stages of clinical trials. Another is under development for onchocerciasis. These vaccines will reduce the rate of infection and reinfection by these parasites and will lower the potential of these parasites becoming resistant to traditional chemotherapy.

Although the incidence of indigenous (endemic) infection is low in the United States and other developed nations, parasitic infections often affect poor people

TABLE 1-1 ■ Estimate of Global Morbidity and Mortality Rates from Major Helminth Infections and Malaria

Parasitic Disease	Number of Infections (in millions)	Global Disease Burden (number of DALYs in millions)	Morbidity (% of world population affected)	Mortality (number of deaths–2010) (% of infected population)
Ascariasis	1,472	10.5	23	60,000 0.004
Hookworm infections	439	22.1	12	65,000 0.005
Trichuriasis	439	6.4	24	10,000 0.001
Lymphatic filariasis	120	5.8	37–40 million suffer	NA
Schistosomiasis	252	4.5	10	20,000 0.01
Onchocerciasis	37	0.5	4.2	45,000 0.25
Dracunculiasis	0.01 million <200 cases 2014	NA	NA	Nearly eradicated in the endemic areas
Strongyloidiasis	100	NA	1.75	70,000,000 1.23
Malaria	216	46.5	5	445,0000 0.5 2016: 29% down since 2010

Note: DALY = disability-adjusted life year

more seriously than they affect the more wealthy inhabitants of the same countries. For example, toxocariasis is one of the most common neglected infections of poverty in the United States. A National Health and Nutrition Examination Survey (NHANES) III (1988–1994) found that 13.9% of the tested population was positive for the presence of *Toxocara* spp. roundworm antigen, due to ongoing or previous infection with a parasite found in domestic dogs and cats. The human *Toxocara* spp. infection is a **zoonosis** acquired by ingesting eggs from dirt in public areas such as city parks and other recreational settings that have become contaminated with animal feces containing viable eggs of this parasite. (See also page 29 in Chapter 2.) In a study published in the Public Library of Science (PLOS), researchers compared the NHANES III 1994 results to newer survey results completed in 2014 and found an overall apparent 9% reduction in seropositivity in the American population. While there was an overall decrease in the disease incidence, the study also found that persistent disparities in the infectivity of various at-risk populations continued to be related to factors of minority ethnicity and low socioeconomic status. These data help to identify factors that can guide workers toward improving the health of various populations.

Other infections may be introduced into various countries by immigrants from tropical areas and by travelers and military personnel returning with "exotic" diseases from foreign endemic areas. "New" disease-causing agents are emerging as opportunistic infections in immunocompromised individuals and, increasingly, waterborne and foodborne parasites such as *Cryptosporidium* spp. are being found in healthy people. Continuing surveillance of parasitic diseases by the Centers for Disease Control and Prevention (CDC), the WHO, and others is necessary to ensure the future health of citizens of the United States and other parts of the world. These organizations observe changes in disease trends around the world so plans can be made and implemented in a timely manner to reduce the impact of various infective agents by providing treatments and possible removal of parasitic forms from the local environment.

WHAT IS PARASITOLOGY?

Parasitology is the study of a particular relationship among certain **species. Symbiosis** means "living together" and generally refers to a positive relationship

between members of different species. **Mutualism** is usually an obligatory relationship in which both organisms benefit. An example of mutualism is the termite and its intestinal flagellate fauna. The termite benefits because it could not digest its cellulose-containing food without the flagellate and the intestinal organism benefits by having a secure habitat in which to live and a good source of food. **Commensalism** is usually not obligatory, but it reflects a relationship in which one species of organism benefits and the other neither benefits nor is harmed. Humans can harbor several species of ameba with no ill effects to the **host** but with benefit to the amebae. These nonpathogenic protozoa, however, are not considered to be true commensals because it is generally accepted that they should not be a normal part of the human intestinal flora. **Parasitism** is a relationship in which one species of organism lives on or with another organism, with the parasite living at the expense of and often causing harm to the host. Most parasites inflict varying degrees of harm depending on the general health and nutritional status of the host, the size of the parasite, the number of parasites present, and the parasites' location or migration path within the host.

Types of Parasites

A parasite that lives inside the host is called an **endoparasite;** one that lives on or in the skin is called an **ectoparasite.** Most parasites are obligate; that is, they must spend part or all of their life cycle within a host to survive. A **facultative parasite** is usually a free-living organism that can become parasitic if it is accidentally ingested or enters a wound or other body opening. *Naegleria fowleri,* an ameba, enters through a person's nose when he or she is swimming in contaminated water. Ectoparasites can be insect forms that interact temporarily or permanently with a human host.

Accidental parasites are those that normally live in or on a host other than humans, and these parasites do not survive long in an unnatural human host. The **accidental (or incidental) host** may or may not experience symptoms. Larvae of dog and cat hookworms that accidentally penetrate human skin or eggs ingested by humans from contaminated soil (*Toxocara* spp.) are examples. Another term used to describe this problem is **zoonosis.**

Hosts

Hosts can be characterized as definitive, intermediate, transport, or reservoir. A **definitive host** is one in which the parasite reaches sexual or reproductive maturity. An **intermediate host** is one that harbors parasites that engage in asexual reproduction. Sometimes both types of hosts are required in a parasite's life cycle.

A **transport host** is one that harbors a parasite that does not reproduce but merely goes on to infect a new host. The transport host serves only to carry the parasite from one location to another. For example, a house fly might passively transfer an ameba on its feet from contaminated feces to a cooking utensil in a kitchen. A new host could then ingest the parasite stage, producing a new infection. A **reservoir host** may harbor a parasite that is also infective for humans. For example, the bush buck antelope often harbors the protozoon that causes sleeping sickness in humans, but the antelope suffers no ill effects.

CLASSIFICATION OF PARASITES

- **I.** The **metazoan** helminths—wormlike invertebrates. (Only those parasitic for humans are included in this text.) The following are considered:
  - **A.** Phylum Nemathelminthes
    - **1.** Class Nematoda: roundworms (body round in cross-section)
  - **B.** Phylum Platyhelminthes: flatworms
    - **1.** Class Cestoda: tapeworms (body flattened and segmented)
    - **2.** Class Digenea: trematodes, flukes (body flattened, leaf-shaped, and nonsegmented)
- **II.** Protozoa*—unicellular eukaryotic microorganisms. The following are considered:
  - **A.** Phylum Sarcomastigophora
    - **1.** Class Lobosea: organisms that move by means of pseudopodia
    - **2.** Class Zoomastigophorea: organisms that move by means of flagella
  - **B.** Phylum Ciliophora
    - **1.** Class Kinetofragminophorea: organisms that move by means of cilia
  - **C.** Phylum Apicomplexa
    - **1.** Class Sporozoa: organisms with both sexual and asexual reproductive cycles; **apical complex** can be seen with an electron microscope
- **III.** Arthropods—possess a hard exoskeleton and jointed appendages. Only those that are parasitic to humans and those that transmit parasitic diseases are included.
  - **A.** Phylum Arthropoda
    - **1.** Class Insecta: flies, mosquitoes, bugs, lice, fleas
    - **2.** Class Arachnida: ticks, mites

* Classification derived from a scheme adopted by the Society of Protozoologists (Cox, 1993).

POST-TEST

Allow 30 minutes for completion of the test. The test is worth 30 points and the points for each question are given below. Write your answers on separate sheets of paper.

1. Define or explain the following terms: (**12 points**)
- **a.** Definitive host
- **b.** Epidemiology
- **c.** Infestation
- **d.** Reservoir host
- **e.** Vector
- **f.** Zoonosis

2. Matching: Each number is used only once: **(6 points)**
- **a.** ____ Obligate parasite
- **b.** ____ Infective stage
- **c.** ____ Disease
- **d.** ____ Transport host
- **e.** ____ Symbiosis
- **f.** ____ Carrier

1. The parasite form that enters a host.
2. Two organisms of different species that are living together.
3. A parasite that cannot survive outside its host.
4. A host harboring a parasite but exhibits no clinical signs or symptoms.
5. A definite morbid process having a characteristic group of symptoms.
6. An animal that harbors a parasite that does not reproduce; the host carries the parasite from one location to another to infect a new host.

The remaining questions are worth 2 points each.

3. A parasite established on or in the body surface of its host is a(n):
- **a.** Cryptoparasite
- **b.** Ectoparasite
- **c.** Endoparasite
- **d.** Facultative parasite
- **e.** Obligate parasite

4. An organism capable of living an independent or a parasitic existence is a(n):
- **a.** Cryptoparasite
- **b.** Ectoparasite
- **c.** Endoparasite
- **d.** Facultative parasite
- **e.** Obligatory parasite

5. The animal in which a parasite passes its larval stage or asexual reproduction phase is a(n):
- **a.** Accidental host
- **b.** Definitive host
- **c.** Intermediate host
- **d.** Reservoir host
- **e.** Vector

6. Which of the following explains how parasitic infections spread to areas other than those where the infections originated?
- **a.** Increase in immunocompromised individuals
- **b.** Increased population density
- **c.** Increased world travel
- **d.** Reduced sanitation conditions

7. The parasitic relationship that allows one organism to benefit but does not cause harm or provide any benefit to the other organism in the relationship is known as:
- **a.** Commensalism
- **b.** Mutualism
- **c.** Parasitism
- **d.** Symbiosis

8. A zoonosis found in the United States that may be acquired in public recreational settings by ingesting eggs from dirt contaminated with dog and cat feces is caused by:
- **a.** *Cryptosporidium* spp.
- **b.** *Ascaris lumbricoides*
- **c.** *Toxocara canis*
- **d.** *Trichuris trichiura*

CHAPTER 2

Nematoda

LEARNING OBJECTIVES FOR CHAPTER TWO

On completion of this chapter and study of its associated plates as described, you will be able to:

1. Define terminology specific for **Nematoda**.
2. State the scientific and common names of all intestinal nematodes for which humans serve as the usual definitive host.
3. State the body specimen of choice to be used for examination to help diagnose nematode infections.
4. State the geographic distribution and relative incidence of medically important nematode infections.
5. Describe the general morphology of an adult nematode.
6. Describe the life-cycle development of parasitic intestinal nematodes from egg through adult stages.
7. Differentiate the adult parasitic intestinal Nematoda by structure and location.
8. Given an illustration or photograph or an actual specimen (if given adequate laboratory experience), identify the diagnostic stages of intestinal Nematoda.
9. Differentiate microfilariae found in infected human blood by the staining patterns of cells in the tail and by the presence or absence of an embryonic sheath.
10. Discuss zoonotic nematode infections of humans and symptoms thereof.
11. Differentiate and discuss methods by which the Nematoda infect humans. Include the scientific name of any required intermediate host and the infective stage for humans.
12. Perform generic identification of parasitic infections by detecting, recognizing, and stating the scientific name of parasites present in biological laboratory specimens (given appropriate laboratory experiences, as described in Chapter 10).

GLOSSARY

autoreinfection. Reinfecting oneself. In the pinworm life cycle, infected individuals may reinfect themselves via hand-to-mouth transfer from scratching the perianal region after the female worm has deposited eggs. In other life cycles, infective eggs may hatch inside the host and then develop into an adult (e.g., *Strongyloides stercoralis, Hymenolepis nana*).

buccal capsule (cavity). Oral cavity of roundworms. (In the case of hookworms, the cavity contains species-specific cutting plates or cutting teeth.)

bursa (pl. bursae). Fan-shaped cartilage expansion at the posterior end of some male nematodes (e.g., hookworms) that holds onto the female during copulation.

copulatory spicules. Needle-like bodies possessed by some male nematodes; spicules lie in pouches near the ejaculatory duct and may be inserted in the vagina of the female worm during copulation.

corticated. Possessing an outer, mamillated, albuminous coating, as on the eggs of *Ascaris lumbricoides.*

cutaneous larval migrans. A disease caused by the migration of larvae of *Ancylostoma* spp. (dog or cat hookworm) or other helminth larvae traveling under the skin of humans. Larval migration is marked by thin, red papular lines of eruption. Also termed *creeping eruption.*

cuticle. The surface of roundworms; a tough protective covering that is resistant to digestion.

dermatitis. Inflammation of the skin.

diagnostic stage. A developmental stage of a pathogenic organism that can be detected in human body secretions, discharges, feces, blood, or tissue by chemical means or microscopic observations. Identification serves as an aid in diagnosis.

diurnal. Occurring during the daytime.

edema. Unusual excess fluid in tissue, causing swelling.

elephantiasis. Overgrowth of the skin and subcutaneous tissue in limbs or genitalia resulting from obstructed circulation in the lymphatic vessels; can occur in the presence of some long-term chronic filaria infections (e.g., *Wuchereria bancrofti*).

enteritis. Inflammation of the intestine.

eosinophilia. High levels of circulating eosinophils in the blood.

fecundity. Reproductive capacity.

filaria (pl. filariae). A nematode worm of the order Filariata; requires an arthropod intermediate host for transmission of infection to humans.

filariformlarva. Infective nonfeeding, sheathed, third-stage larva; larva has a long, slender esophagus.

gravid. Pregnant; female has developing eggs, embryos, or larvae in reproductive organs.

heterogonic life cycle. Free-living stage of life cycle of an organism (e.g., *Strongyloides stercoralis*) that also has a parasitic stage.

homogonic life cycle. Parasitic stage of life cycle of an organism (e.g., *Strongyloides stercoralis*) that also has a free-living stage.

immunocompromised (immunosuppressed state). Depressed immune response system state; can accompany various diseases or can be induced by drugs.

incubation period. The time from initial infection until the onset of clinical symptoms of a disease.

infective stage. The stage of the life cycle at which the parasite is capable of entering and continuing development within the host.

intermediate host. A species of animal that serves as a host for only the larval or sexually immature stages of parasite development. Required part of the life cycle of that parasite.

larva (pl. larvae). An immature stage in the development of a worm before becoming a mature adult. Nematodes **molt** several times during development, and each subsequent larval stage is increasingly mature.

life cycle. Entrance into a host, growth, development, reproduction, and subsequent transmission of offspring to a new host.

microfilaria (pl. microfilariae). The embryo stage of a filaria parasite; usually in the blood or tissue of humans; can be ingested by the arthropod intermediate host in which the microfilaria will develop to the infective stage.

molt. A process of replacement of the old cuticle with an inner, new one and subsequent shedding of the old, outer cuticle to allow for the growth and development of the larva; the actual shedding of the old cuticle is termed *ecdysis.*

Nematoda. A class of the animal phylum Nemathelminthes–the roundworms.

occult. Hidden; not apparent.

pathenogenic. Capable of unisexual reproduction; no fertilization is required (e.g., *Strongyloides stercoralis* parasitic female).

pathognomonic. Indicative of disease; characteristic parthenogenic symptoms suggest the disease.

periodicity. Recurring at a regular time period.

pica. Habit of eating dirt or other unusual substances, such as chalk or plaster. Seen most often in children or rarely, in adults.

prepatent period. The time elapsing between initial infection with the immature parasite and reproduction by the adult parasite.

pruritus. Intense itching. *Pruritus ani* refers to anal itching, as in enterobiasis.

rectal prolapse. Weakening of the rectal musculature resulting in a "falling down" of the rectum; occasionally seen in heavy whipworm infections, particularly in children.

rhabditiform larvae. Noninfective, feeding, first-stage larvae; the larvae have an hourglass-shaped esophagus.

tropical eosinophilia. A disease syndrome associated with high levels of blood eosinophils and an asthma-like syndrome. Caused by zoonotic filaria (or other nematode) infections in which no microfilariae are detectable in peripheral blood in most cases.

visceral larval migrans. A disease in humans caused by the migration of the larval stage of the roundworm *Toxocara canis* or *T. cati* through the liver, lungs, or other organs. The normal host of these ascarids is the dog or cat. The disease is characterized by hypereosinophilia and hepatomegaly and often by pneumonia. Migrating **larvae** can invade ocular spaces and cause retinal damage. This migration is called ocular larval migrans (OLM).

INTRODUCTION

The class Nematoda includes both metabolically independent free-living species and parasitic species that have a metabolic dependence on one or more host species to continue their life cycles. As a group, the nematodes are referred to as *roundworms* because they are round when viewed in cross-section. The different species vary in size from a few millimeters to more than 1 meter in length. There are separate sexes, with the male generally being smaller than the female. The male often has a curved or coiled posterior end with **copulatory spicules** and, in some species, a **bursa.** The adult anterior end may have oral hooks, teeth, or plates in the **buccal capsule (cavity)** for the purpose of attachment. It also may have small body surface projections, known as *setae* or *papillae,* which are thought to be sensory in nature. Body development is fairly complex. The exterior resistant surface of the adult worm is called the **cuticle;** this is underlain with several muscle layers. The internal organ systems include a complex nerve cord; a well-developed digestive system (oral buccal capsule, muscular esophagus, gut, and anus); and complete, tubular, coiled reproductive organs, which are proportionally very large and complex. In the male, reproductive organs include the testes, vas deferens, seminal vesicle, and ejaculatory duct. The female reproductive organs include two ovaries, oviducts, uterine seminal receptacle, and vagina. A female can produce from several hundred up to millions of offspring, depending on the species. **Fecundity** is usually proportional to the complexity of the life cycle of the parasite—those involving direct-contact transmission to a new host produce the fewest offspring; those requiring multiple hosts often produce the most.

Humans are the definitive host for the roundworms of medical importance because humans harbor the reproducing adult roundworms. Depending on the species, the adult female nematode produces either fertilized eggs or **larvae** that may be infective to a new host by one of three routes: (1) Eggs may be immediately infective by being ingested, (2) eggs or larvae may require a period of external development to reach the infective stage, or (3) an insect may transmit eggs or larvae to a new host. Developing larvae generally go through a series of four molts during the **incubation period.**

Most often it is the third-stage larva (the **filariform** stage) that is infective. Infection of humans with different species of roundworms is by ingestion of the infective stage egg or larva, by larval penetration through the skin of the host, or via transmission of larvae by the bite of an insect. The development of a parasite to the infective stage, the manner in which humans become infected, and the life cycle are different for each parasite species.

Of the species of nematodes that are parasitic for humans, about half reside as adult worms in the intestinal tract; the other species are found as adults in various human tissues. The pathogenicity of intestinal nematodes may be due, in part, to migration of adults or larvae through human tissues such as liver or lungs, piercing of the intestinal wall, bloodsucking activities of adult worms, or allergic reactions to substances secreted or excreted by either adult worms or larval stages. This can be serious in heavy infections. Pathogenicity induced by the tissue-dwelling adult roundworms primarily results from immune and nonspecific host responses to the parasite secretions and excretions and to degenerating parasite material. In some cases, it may result from circulating larval stages. Migrating nematodes are usually associated with blood or tissue **eosinophilia.** Most infected persons have low worm burdens and modest symptoms.

INTESTINAL NEMATODES

Table 2-1 lists the scientific genus and species names and the common names for the intestinal roundworms of medical importance that are included in this section. On the following pages are the life-cycle diagrams, disease names, some of the major pathology and symptoms caused by infection with these roundworms, distribution, and other points of diagnostic importance. Also study the corresponding pictures and descriptive key found in the Atlas (Plates 1 to 27) at the front of the book.

Table 2-2 will help you review the pertinent information for each parasite, including the epidemiology and the major disease manifestations that these parasites cause. The second section of this chapter covers the Filariae, tissue nematodes, in the same manner as

TABLE 2-1 ■ Intestinal Roundworms

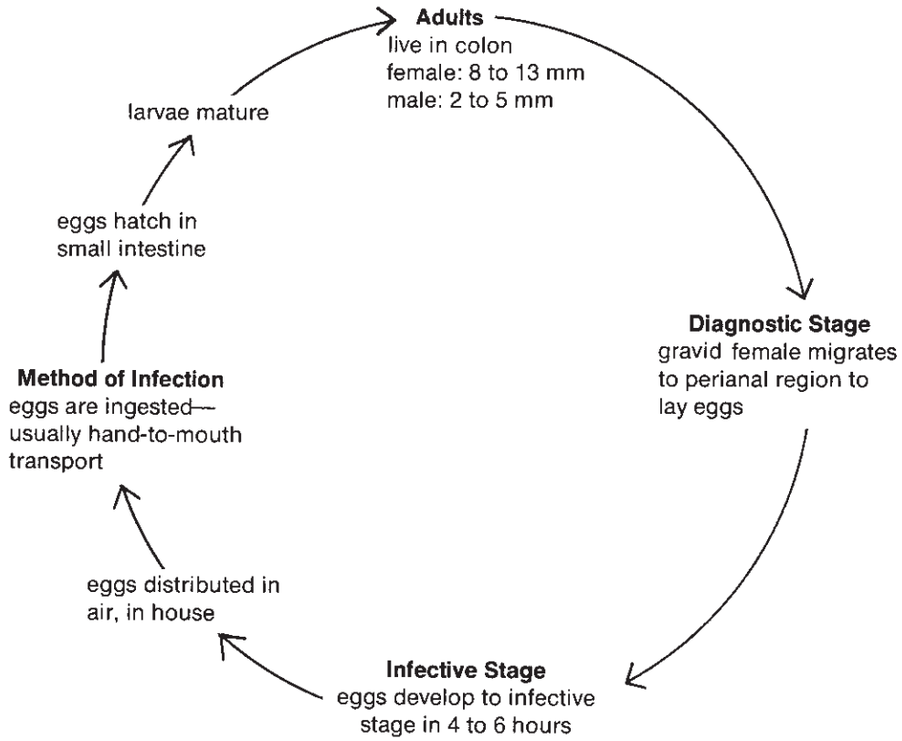
Order	Scientific Name (genus and species)	Common Name
Ascaridida	*Enterobius vermicularis* (en"tur-o'bee-us/vur-mick-yoo-lair'is)	pinworm, seatworm
Trochocephalia	*Trichuris trichiura* (Trick-yoo'ris/trick"ee-yoo'ruh)	whipworm
Ascaridida	*Ascaris lumbricoides* (as-kar-is/lum-bri-koy'deez)	large intestinal roundworm
Strongylida	*Necator americanus* (ne-kay'tur/ah-merr"I-kay'nus)	New World hookworm
Strongylida	*Ancylostoma duodenale* (An"si-los'tuh'muh/dew'o-de-nay'lee)	Old World hookworm
Rhabditida	*Strongyloides stercoralis* (Stron"ji-loy'-deez/stur"ko-ray'lis)	threadworm
Trichocephalida	*Trichinella spiralis* (trick"i-nel'uh/spy-ray'lis)	trichina worm

TABLE 2-2 ■ Important Intestinal Nematode Infections

Scientific and Common Name	Epidemiology	Disease-Producing Form and Its Location in Host	How Infection Occurs	Major Disease Manifestations, Diagnostic Stage, and Specimen of Choice
Enterobius vermicularis (pinworm)	Worldwide	Adult worms in colon, eggs on perianal region	Infective eggs are discharged by the gravid female on perianal skin; eggs are transferred from hand to mouth	Perianal itching caused by local irritation from scratching; diagnosis: eggs found by cellophane test (p. 164)
Trichuris trichiura (whipworm)	Worldwide, especially in moist, warm climates	Adult worms in colon	Ingestion of eggs containing mature larvae from infected soil or food	Light infection—asymptomatic; heavy infection—enteritis, diarrhea, rectal prolapse; diagnosis: eggs in feces
Ascaris lumbricoides (large intestinal roundworm)	Worldwide, especially in moist, warm climates	Larval migration through liver and lungs, adult worms in small intestine	Ingestion of eggs containing mature larvae from infected soil or food	Light infection—asymptomatic; heavy infection—pneumonia from larval migration, diarrhea, and bowel or appendix obstruction; diagnosis: eggs or adults in feces
Trichinella spiralis (trichina worm)	Worldwide	Adults in small intestine, larval migration, larvae encyst in striated muscle	Ingestion of encysted larva in undercooked meat (pork or bear)	Gastric distress, fever, eye edema, acute muscle pain, eosinophilia; diagnosis: encysted larvae in muscle biopsy; serology
Necator americanus (New World hookworm)	United States, West Africa, Asia, and South Pacific	Larval migration, ground itch, adults in small intestine	Eggs shed in feces, mature in soil, larvae hatch and mature, infective (filariform) larvae penetrate host skin, especially feet	Repeated infection results in larval **dermatitis** with later pulmonary symptoms, microcytic hypochromic anemia from chronic blood loss if heavy infection and poor diet; diagnosis: eggs in feces
Ancylostoma duodenale (Old World hookworm)	Europe, Brazil, Mediterranean area, and Asia	As for *Necator americanus*	As for *Necator americanus*	As for *Necator americanus*
Strongyloides stercoralis (threadworm)	Worldwide, warm areas	Larval migration, pulmonary signs, adults in small intestine	Immature (rhabditiform) larvae are shed in feces, develop in soil; infective (filariform) larvae penetrate host skin, especially feet; autoreinfection by maturing larvae in intestine; soil-dwelling, nonparasitic adults may produce additional infective-stage larvae	Repeated infection results in larval dermatitis with later pulmonary symptoms, heavy infections—abdominal pain, vomiting, and diarrhea; moderate eosinophilia, immunosuppressed host may suffer severe symptoms or death from heavy worm burdens inasmuch as autoinfection may occur; diagnosis: rhabditiform larvae in feces
Dracunculus medinensis (Guinea worm)	Africa, Asia, South America; no periodicity; *Cyclops* (crustacean)	Adults live in subcutaneous tissues, females migrate (larvae released from skin ulcer)	Ingestion of water containing crustaceans infected with larvae	Systemic allergic symptoms and local ulcer formation; diagnosis: adult in skin ulcer, larvae released into water

the intestinal nematodes, and the third section discusses nematode zoonoses. All other chapters of this book follow the same format. Remember: When you think you have mastered these chapter materials (as outlined in the learning objectives), you will be ready to take the post-test on the section. The directions for each test are included on the test pages and the answer key begins on page 201.

Enterobius vermicularis (pinworm, seatworm)



Method of Diagnosis

Recover eggs or yellowish white female adult from perianal region with a cellophane tape preparation taken early in the morning when the patient first wakes (Fig. 2-1) (see Chapter 10, p. 164).

Diagnostic Stage

Disease Names

- Enterobiasis
- Pinworm or seatworm infection

Major Pathology and Symptoms

1. Many cases are asymptomatic. Occasionally, severe clinical problems develop.

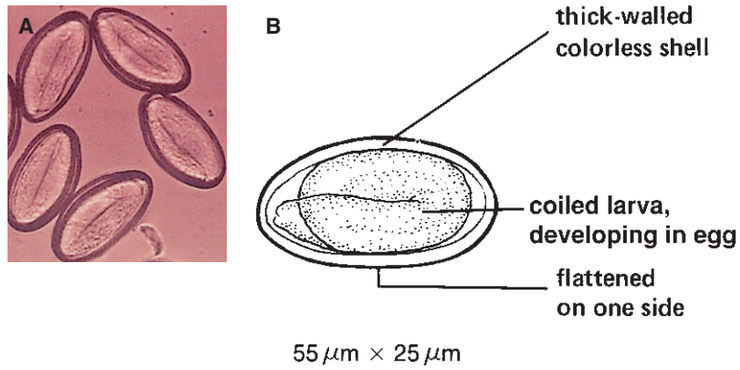


FIGURE 2-1 **A.** *Enterobius vermicularis* eggs (400×). **B.** Egg structures.

2. Rarely, the disease causes serious lesions, which are usually limited to minute ulcers and mild inflammation of the intestine. About half of all patients report abdominal pain.
3. Other symptoms are associated with the migration of the gravid female out from the anus to lay her eggs on the perianal region at night.
   - **a.** Cardinal feature: Hypersensitivity reaction from **autoreinfection** causing severe perianal itching; eggs get on hands from scratching and are ingested; **pruritus** ani is **pathognomonic**
   - **b.** Mild nausea or vomiting
   - **c.** Loss of sleep and irritability
   - **d.** Slight irritation to intestinal mucosa
   - **e.** Vulval irritation in girls from migrating worms entering vagina

Treatment

Mebendazole or pyrantel pamoate; warm tap-water enemas; may need to treat the whole household because eggs are easily spread in the environment.

Distribution

Distribution is worldwide, but it is more prevalent in temperate climates. *E. vermicularis* is the most common helminth infection in the United States. It is a group infection, especially common among children.

Of Note

1. Humans are the only known host. Infection is generally self-limiting.
2. Each female produces up to 15,000 eggs. Most eggs become infective within 4 hours of release and remain infective for only a few days. Cleaning eggs from the environment and treating all persons in the household are important to break the life cycle.
3. Eggs are rarely found in fecal samples because release is external to the intestine. Adult females occasionally can be recovered on cellophane tape preparation used to find eggs on the perianal area.
4. Hatched larvae on perianal area may migrate back into the rectum and large intestine and develop into adults (retroinfection) or autoreinfection (ingestion of eggs) can occur.

FOR REVIEW

1. Write the scientific name for seatworm:

   _____

   _____

2. Draw and label a picture of the diagnostic stage for this parasite.

3. The diagnostic test for this parasite is the

   _____

   test and is best performed in the a.m. _____

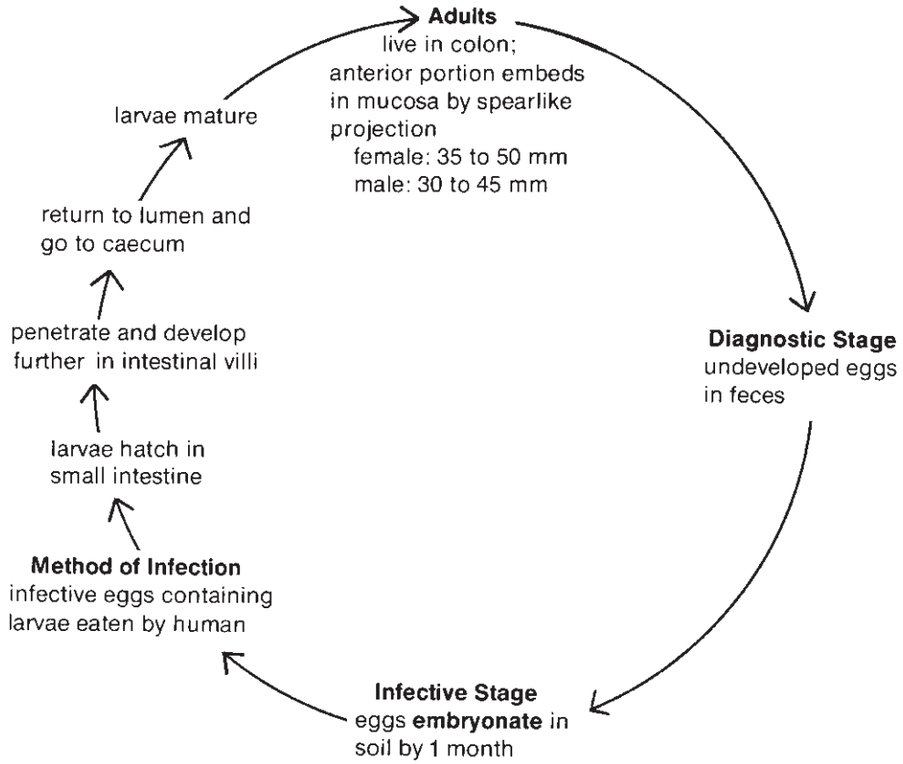
   or p.m. _____.

4. This infection can be increased in the host by

   _____

   or _____.

Trichuris trichiura (whipworm)



Method of Diagnosis

Recover and identify characteristic eggs in feces (Fig. 2-2).

Disease Names

- Trichuriasis
- Whipworm infection

Diagnostic Stage

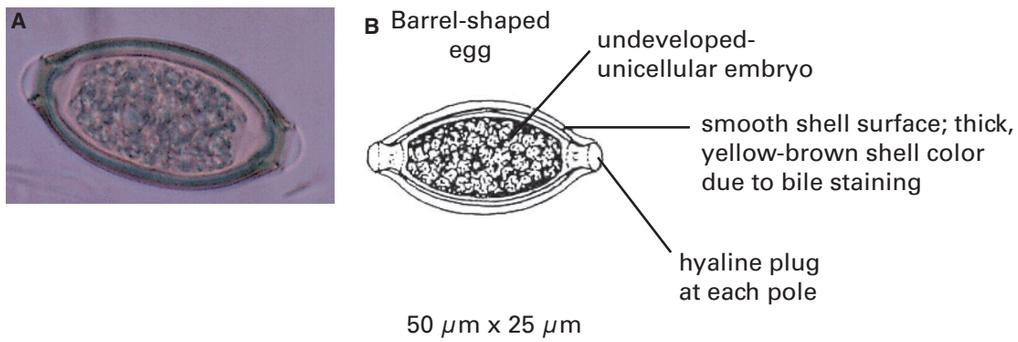


FIGURE 2-2 **A.** *Trichuris trichiura* egg (4×). **B.** Egg structures.

Major Pathology and Symptoms

1. Persons with slight infection are asymptomatic, with no treatment required.
2. Heavy infection (500 to 5,000 worms) simulates ulcerative colitis in children and inflammatory bowel disease in adults. Histology reveals eosinophil infiltrations but no decrease in goblet cells. The surface of the colon may be matted with worms. Patients will have:
   - **a.** Bloody or mucoid diarrhea
   - **b.** Weight loss and weakness
   - **c.** Abdominal pain and tenderness (colitis may be seriously debilitating)
   - **d.** Increased peristalsis and **rectal prolapse,** especially in children
3. Chronic infections in children can stunt growth.
4. Stool is loose with mucus (and obvious blood) in heavy infection.

Treatment

Abendazole, Mebendazole, Ivermectin

Distribution

T. trichiura is prevalent in warm countries and areas of poor sanitation. In the United States, it is prevalent in the warm, humid climate of the South. It is the third most common intestinal helminth in the United States. It is more common among children and mentally disabled people.

Of Note

1. Double infections commonly occur with *Ascaris* because of the similar method of human infection (i.e., ingestion of eggs from fecally contaminated soil). Pica is not an unusual occurrence in children.
2. Drug treatment may cause production of distorted eggs that have bizarre shapes when seen in a fecal specimen.
3. Zoonosis infection can occur with pig or dog species of whipworm.

FOR REVIEW

1. Draw the life cycle for whipworm.

2. Draw and label a picture of the diagnostic stage for this parasite.

3. Why are children more commonly infected than adults?

   _____

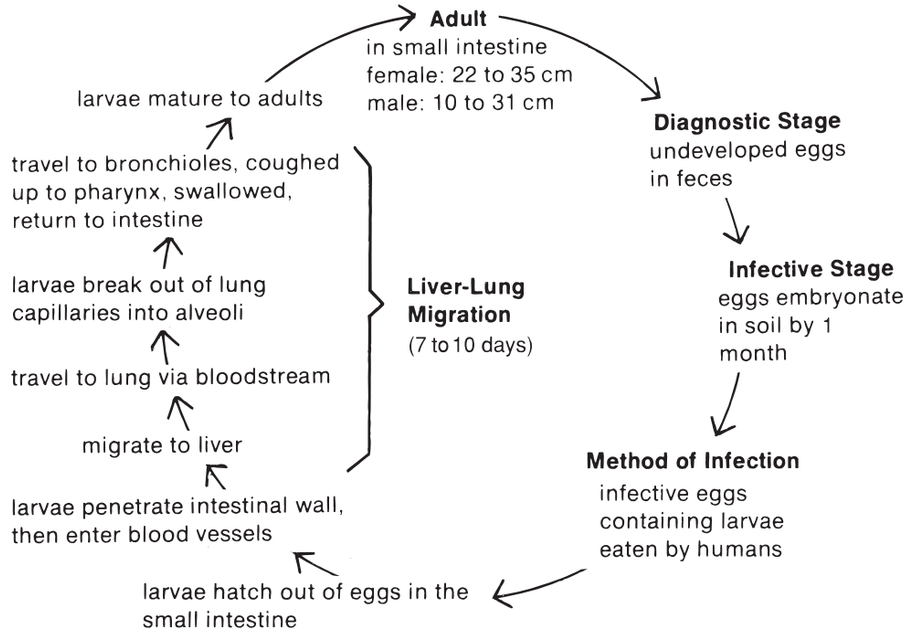
   _____

4. Double infections can occur most commonly with

   _____

   _____.

Ascaris lumbricoides (large intestinal roundworm)



Method of Diagnosis

Recover and identify fertile (corticated or not) or infertile eggs in feces (Figs. 2-3 and 2-4). Sedimentation concentration test is recommended instead of flotation. Enzyme-linked immunosorbent assay (ELISA) serologic test is available.

Disease Names

- Ascariasis
- Roundworm infection
- Large intestinal roundworm infection

Major Pathology and Symptoms

1. Tissue phase: With heavy or repeated infection, pneumonia, cough, low-grade fever, and 30% to

Diagnostic Stage

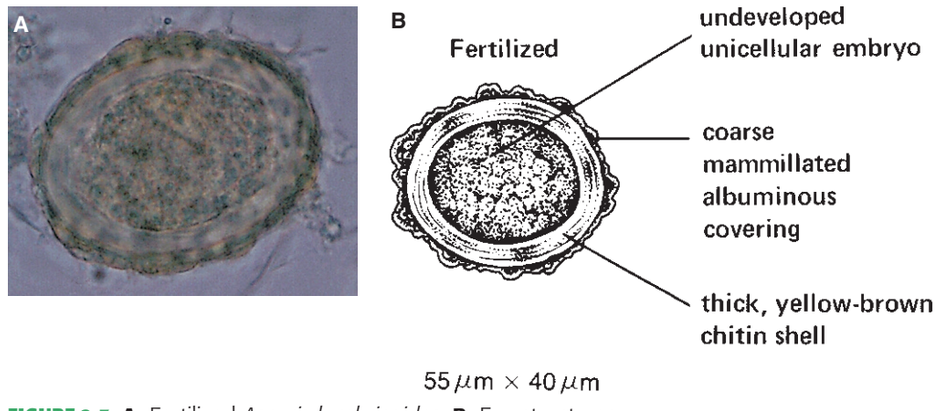


FIGURE 2-3 **A.** Fertilized *Ascaris lumbricoides*. **B.** Egg structures.

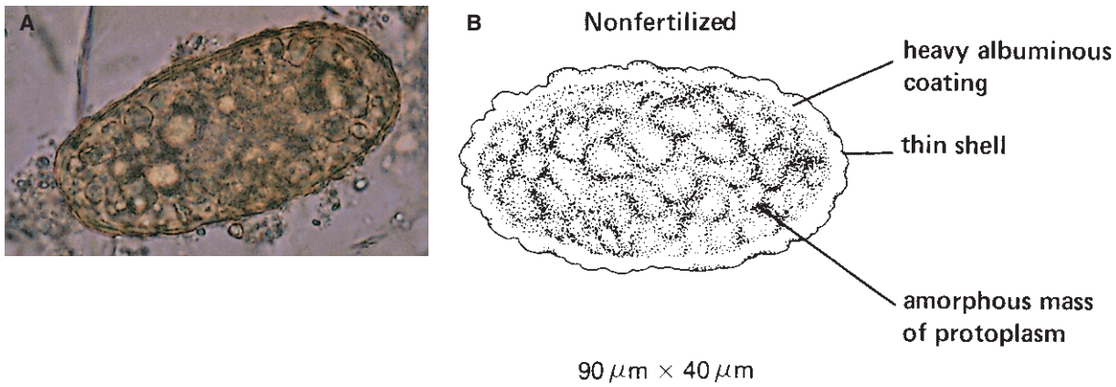


FIGURE 2-4 **A.** Nonfertilized *Ascaris lumbricoides*. **B.** Egg structures.

50% eosinophilia (Löffler's syndrome) result from migration of larvae through the lungs (1 to 2 weeks after ingestion of eggs). Allergic asthmatic reaction may occur with reinfection.

2. Intestinal phase: Intestinal or appendix obstruction results from migrating adults in heavy infections.
   - **a.** Vomiting and abdominal pain result from adult migration.
   - **b.** Protein malnutrition can occur in children with heavy infections and poor diets.
   - **c.** Some patients are asymptomatic.
3. Complications from intestinal obstruction are caused by tangling of the large worms or migration of adults to other sites, such as the appendix, bile duct, or liver (detectable by radiograph).
4. Migrating adults (22 to 35 cm long) may exit by the nose, mouth, or anus. They are large, creamy, and white and have a cone-shaped tapered anterior; the male has a curved tail.

Treatment

1. Mebendazole or pyrantel pamoate
2. Piperazine citrate
3. Levamisole
4. Corticosteroid treatment (helps symptoms of severe pulmonary phase)
5. Nasogastric suction and drug treatment or surgery for intestinal obstruction by adults

Distribution

A. Lumbricoides is prevalent in warm countries and areas of poor sanitation. It coexists with *T. trichiura* in the United States, which is found predominantly in the Appalachian Mountains and adjacent regions to the east, south, and west. The eggs of these two species require the same soil conditions for development to the infective state, and infection for both is by ingestion of infective eggs.

Of Note

1. *Ascaris* is the largest adult intestinal nematode.
2. Adults are active migrators when provoked by fever, certain drugs, and anesthesia, and they may tangle and block the intestine or migrate through the intestine or appendix and come out of the mouth or anus. Mortality mainly results from intestinal complications in heavy infections.
3. *Ascaris* is the second most common intestinal helminth infection in the United States and the most common infection worldwide.
4. The adult female lays up to 250,000 eggs per day.
5. Eggs may remain infective in soil or water for years; they are resistant to chemicals.

FOR REVIEW

1. Write the scientific name for the large intestinal roundworm:

   _____

   _____

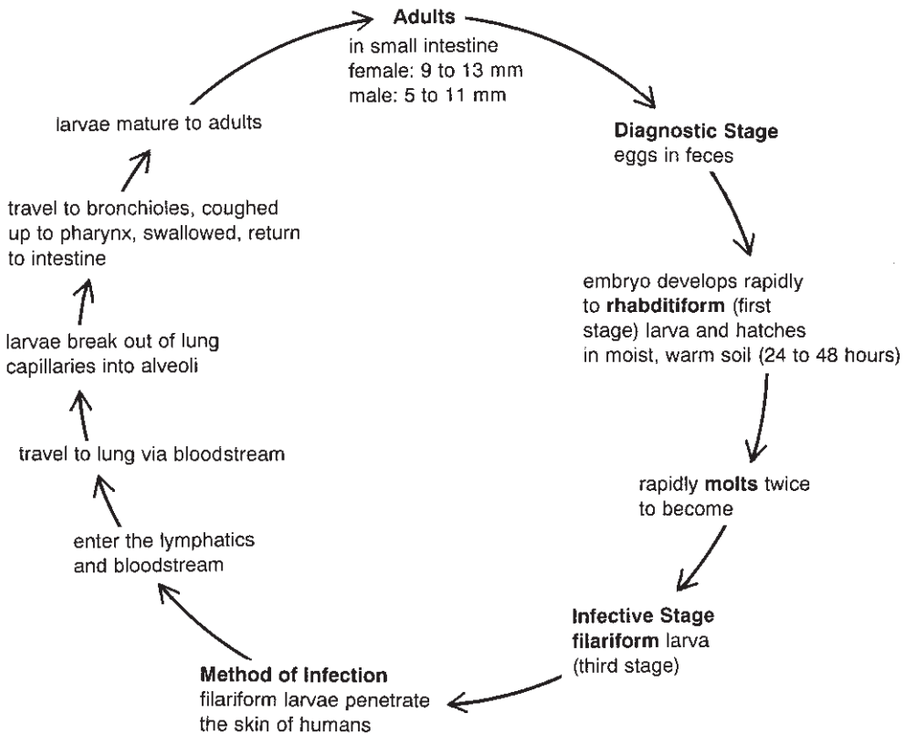
2. Draw and label pictures of the two diagnostic forms of the eggs of this parasite.

3. List the route of the migration of the larva after it escapes from the eggshell.

   _____

   _____

Necator americanus (New World hookworm) *and Ancylostoma duodenale* (Old World hookworm)



Method of Diagnosis

Recover and identify hookworm eggs in fresh or preserved feces. Species cannot be differentiated by egg appearance (Fig. 2-5).

Diagnostic Stage

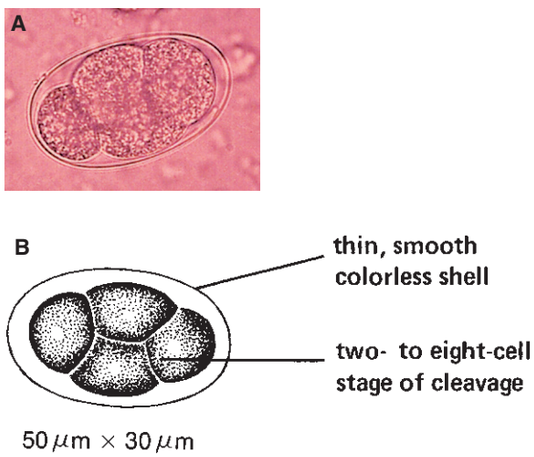


FIGURE 2-5 **A.** *Necator americanus* and *Ancylostoma duodenale*. **B.** Egg structures.
Note: *Eggs of these species are almost identical.*

Disease Name

■ Hookworm disease

Major Pathology and Symptoms

1. After repeated infection, severe allergic itching develops at site of skin penetration by infective larvae; this condition is known as "ground itch." Penetration stings and an erythematous papule forms.
2. Larvae migrate through lungs: Intra-alveolar hemorrhage and mild pneumonia with cough, wheezing, sore throat, bloody sputum, and headache occur in heavy infections. Reaction is more severe in reinfections.
3. Intestinal phase of infection:
   a. Acute (heavy worm burden producing more than 5,000 eggs per gram [EPG] of feces): enteritis, epigastric distress in 20% to 50%, anorexia, diarrhea, pain, microcytic hypo-chromic iron deficiency anemia with accompanying weakness, signs of hypoproteinemia, edema, and loss of strength from blood loss caused by adult worms
   b. Chronic light worm burden showing fewer than 500 EPG is the usual form of this infection;

slight anemia, weakness, or weight loss; nonspecific mild gastrointestinal symptoms (may be subclinical)

c. Symptoms secondary to the iron deficiency anemia caused by blood loss; hyperplasia of bone marrow and spleen

d. High eosinophilia

Treatment

Mebendazole or pyrantel pamoate, iron-replacement therapy, thiabendazole ointment for **cutaneous larval migrans.**

Distribution

N. americanus is found in North and South America; Asia, including China and India; and Africa. *A. duodenale* is found in Europe; South America; Asia, including China; Africa; and the Caribbean. Other Ancylostoma species are found in the Far East. Hookworms are common in agrarian areas with poor sanitation. Almost one-fourth of the world's population is assumed to be infected with hookworms.

Of Note

1. Moist, warm regions and bare-skin contact with sandy soil are optimal conditions for contracting heavy infections in areas of poor sanitation. These parasites are often found in the same soil conditions as *Ascaris* and *Trichuris.*

2. Delayed fecal examination can result in larval development and egg hatching; therefore, *Strongyloides* larvae must be differentiated from hookworm larvae (see Atlas Plates 21 and 25). Hookworm rhabditiform larvae have a long buccal capsule; *Strongyloides* rhabditiform larvae have a short buccal capsule and a bulbous esophagus.

3. Adults are voracious bloodsuckers. Heavy infection can result in 100 mL of blood loss per day; therefore, provide dietary and iron therapy support along with drug treatment, as necessary.

4. Animal species of hookworm larvae such as *A. braziliense* can migrate subcutaneously through the human skin after penetration, causing allergic reaction in the migration tracks (cutaneous larval migrans).

5. Differentiate adults by buccal capsule and bursa (see Atlas Plates 21 and 25).

6. *Ancylostoma* filariform larvae can infect orally and possibly by transmammary or transplacental passage.

7. Pica contributes to infection and is a common symptom.

FOR REVIEW

1. Write the scientific and common names for the two hookworm species:

_____

and _____

2. Why might you find hookworm larvae in a fecal specimen?

_____

_____

3. Describe how the two species are differentiated.

_____

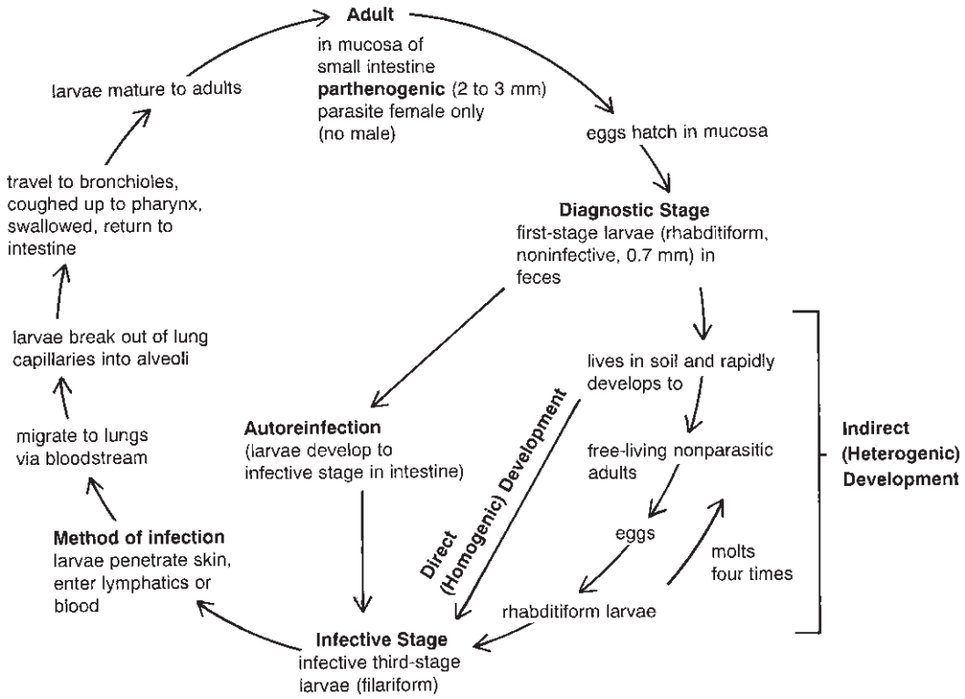
_____

4. The infective larval form is also called the

_____

_____.

Strongyloides stercoralis (threadworm)



Method of Diagnosis

Recover and identify rhabditiform larvae in feces, which are present in low numbers (Fig. 2-6). Also, the presence of hookworm-like eggs or larvae in duodenal drainage fluid or from Entero-Test capsule is diagnostic. (Larvae must be differentiated from hookworm larvae when found in feces; see Atlas Plates 21 and 25.) Serology is EIA. Larvae may be in sputum in disseminated strongyloidiasis. In severe cases, intestinal radiograph shows loss of mucosal pattern, rigidity, and tubular narrowing.

Disease Names

- Strongyloidiasis
- Threadworm infection

Major Pathology and Symptoms

1. Major clinical features are abdominal pain, diarrhea, and urticaria, with eosinophilia.
2. Skin shows recurring allergic, raised, itchy, red wheals from larval penetration.
3. Migration of larvae: Primary symptoms are in the lungs; bronchial verminous (from worms) pneumonia.

Diagnostic Stage

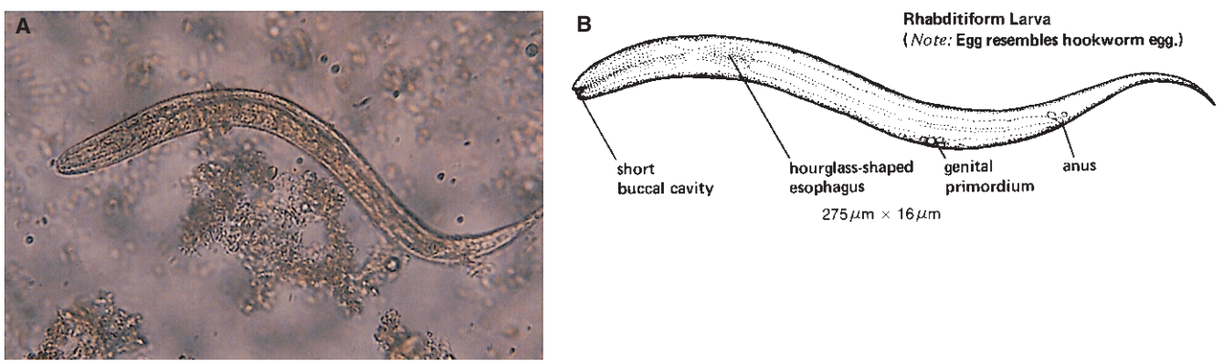


FIGURE 2-6 **A**. *Strongyloides stercoralis* rhabditiform larvae. **B.** Larvae structures.

4. Intestinal symptoms include abdominal pain, diarrhea, constipation, vomiting, weight loss, variable anemia, eosinophilia, and protein-losing enteropathy. Light infections are often asymptomatic; gross lesions are usually absent. The bowel is edematous and congested with heavy infection.
5. *S. stercoralis* has caused sudden deterioration and death in immunocompromised persons because of heavy autoinfection and larval migration throughout body (hyperinfection), with bacterial infection secondary to larval spread and intestinal leakage.

Treatment

1. Thiabendazole (not always successful)
2. Albendazole
3. Ivermectin

Distribution

Distribution is in warm areas, tropics, and subtropics worldwide (similar to hookworm).

Of Note

1. The parasitic female is parthenogenic; therefore, multiplication and autoreinfection can develop in the same host.
2. Internal infection can continue for years because of maintenance of autoreinfection.
3. Strongyloidiasis is difficult to treat.
4. Often, T-lymphocyte function is defective.
5. *Strongyloides* larvae are not recovered using the zinc sulfate flotation technique; the sedimentation concentration method is preferred.
6. *S. stercoralis* has a **heterogonic life cycle** that consists of a parasitic generation and a free-living generation. The parasitic stage has a **homogonic life cycle**, while the free-living stage has a heterogonic life cycle. The heterogonic life cycle is advantageous to the parasite because it allows reproduction for one or more generations in the absence of a host. Environmental conditions influence the production of infectious larvae.

FOR REVIEW

1. Write the scientific name for the threadworm:

_____

_____

2. How can you recover and identify the diagnostic stage for this parasite?

_____

_____

3. List the characteristic(s) that differentiate this parasite's first-stage larvae from hookworm larvae.

_____

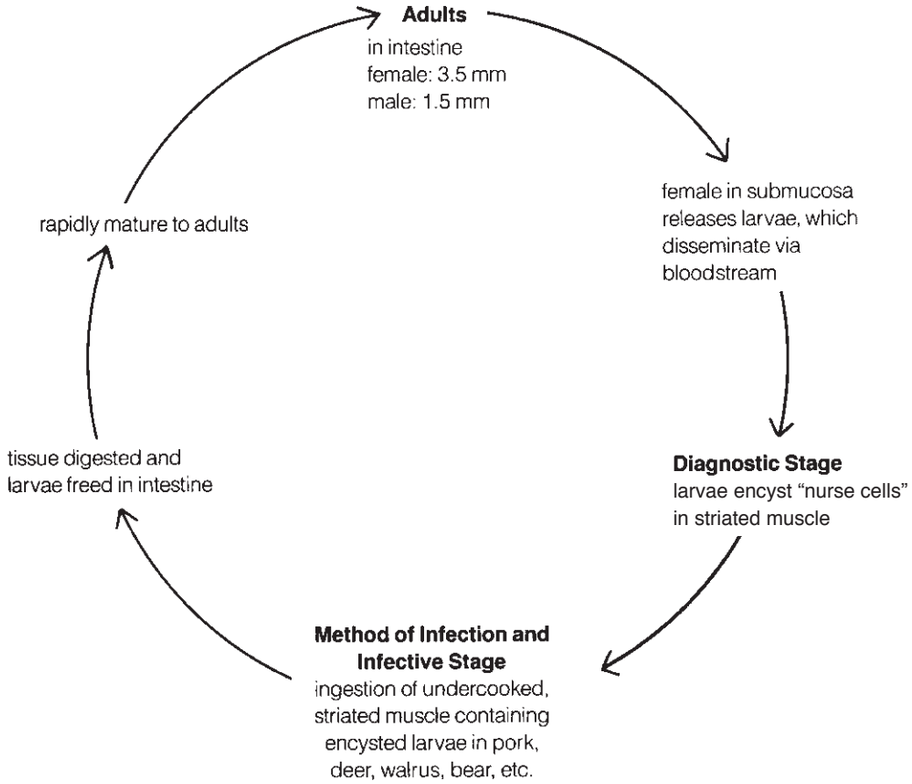
_____

4. Which concentration technique is preferred for this parasite?

_____

_____

Trichinella spiralis (trichinosis; trichinellosis)



Method of Diagnosis

Identification of encysted larvae in biopsied muscle; serologic testing (ELISA) 3 to 4 weeks after infection (Fig. 2-7). A history of eating undercooked pork or bear, fever, muscle pain, bilateral periorbital **edema,** and rising eosinophilia warrants presumptive diagnosis.

Diagnostic Stage

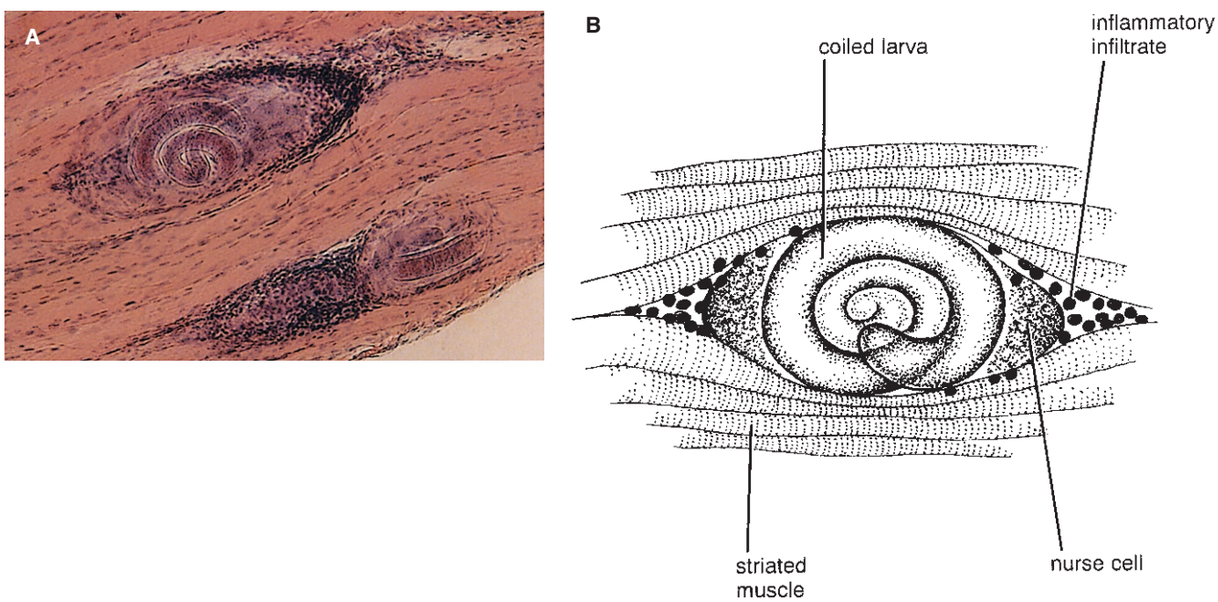


FIGURE 2-7 **A**. *Trichinella spiralis* larva encysted in a muscle cell (called the "nurse cell"; granuloma forms around nurse cell and becomes calcified over time). **B.** Larva structures.

Disease Names

- Trichinosis
- Trichinellosis

Major Pathology and Symptoms

1. Intestinal phase shows small intestine edema and inflammation, nausea, vomiting, abdominal pain, diarrhea, headache, and fever (1st week after infection).
2. Migration phase shows high fever (104°F), blurred vision, edema of the face and eyes, cough, pleural pains, and eosinophilia (15% to 40%) lasting 1 month in heavy infection; death can occur during this phase in 4th to 8th week after infection.
3. Muscular phase shows acute local inflammation with edema and pain of the musculature. Other symptoms vary depending on the location and number of larvae present. Larvae encyst in skeletal muscles of limbs, diaphragm, and face, but they invade other muscles as well. Weakness and fatigue develop.
4. Focal lesions show periorbital edema, splinter hemorrhages of fingernails, retinal hemorrhages, and rash.

Treatment

1. Nonlife-threatening infection (self-limiting): rest, analgesics, and antipyretics
2. Life-threatening infection: prednisone; thiabendazole (caution—effectiveness not proven; may have side effects)

Distribution

Distribution is worldwide among meat-eating populations and rare in the tropics. The prevalence in the United States is low with an average of 16 cases recognized and reported per year in the United States from 2011 to 2015. Additionally, other cases have been brought to the United States by immigrants from Mexico and other Central American countries. Most cases were acquired by eating undercooked, infected wild game, especially bear meat. However, the continued identification of cases related to both pork and nonpork sources indicates that public education about trichinellosis and the dangers of consuming raw or undercooked meat still is needed. Hunters and consumers of wild game meat should be educated about the risk associated with consumption of raw or undercooked meat.

Of Note

1. Zoonosis: Carnivorous mammals are the primary hosts. This condition is found in most species.
2. Multiple cases are often related to one source of undercooked infected meat.
3. Cooking meat to 137°F or freezing for 20 days at 5°F will kill larvae.

FOR REVIEW

1. Write the scientific name for trichinosis:

   _____

   _____

2. Describe the diagnostic stage and method of diagnosis for this parasite.

   _____

   _____

3. What is the characteristic feature seen in peripheral blood during the migration phase of the life cycle?

   _____

   _____

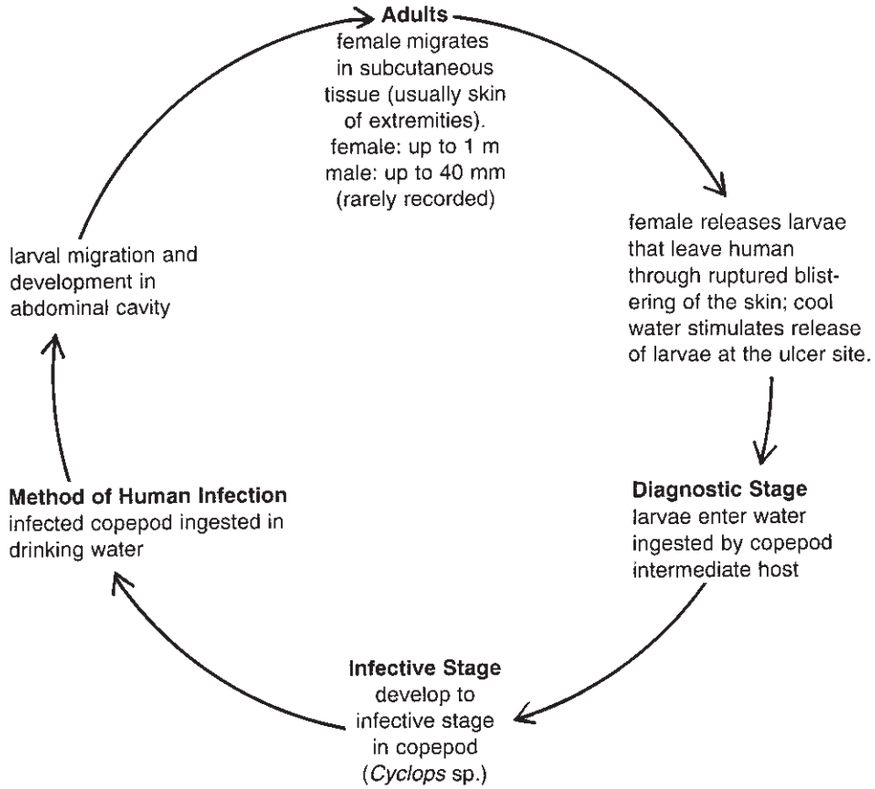
4. List three animals that may harbor this parasite:

   _____,

   _____,

   and _____

Dracunculus medinensis (Guinea worm)



Method of Diagnosis

Visually observe painful skin blisters or emerging worm; induce release of larvae from skin ulcer when cold water is applied.

Disease Names

- Dracunculus
- Guinea worm

Major Pathology and Symptoms

1. Allergic reaction occurs during migration.
2. The papule develops into a blister, usually on the feet or legs, that ruptures.
3. Secondary bacterial infections or reaction to aberrant migration of larvae or adults may cause disability or death.

Treatment

1. Removal of adult from skin (slow withdrawal from blister by wrapping it around a revolving small stick over several days; this process may be completed in a few days but usually requires weeks or even months)
2. Surgical removal of adult
3. Aspirin for pain; antihistamines may reduce swelling
4. Prevention of secondary infection

Distribution

D. medinensis is found in the Middle East, India, Pakistan, and Africa.

Of Note

1. *D. medinensis* is the largest adult nematode parasitic in humans.
2. There is no effective immunity to reinfection.
3. The World Health Organization (WHO) and other international foundations have worked to eradicate *D. medinensis* worldwide through the promotion of drinking water filtration (T-shirts or gauze can be used) to strain out infected copepods. The WHO also sponsors an education campaign to keep people out of the water when adult worms are protruding from the body. Since 1986 the total worldwide caseload has dropped from about 3.5 million to less than 18,000 cases in 2010 because of the eradication efforts of these organizations. India and Pakistan are both free of Dracunculiasis. Great success has occurred in Africa with Ethiopia, Chad, Mali, and South Sudan being the last African countries to still have reported cases of Guinea worm, one of the neglected tropical diseases. Incidences of Guinea worm disease have been reduced from an estimated 3.5 million in 1986 to 30 in 2017. It is finally possible to believe that Dracunculiasis will be eradicated within the foreseeable future.

FOR REVIEW

1. Write the scientific name for Guinea worm:

2. Describe the method of transmission for this parasite.

Review Table 2-2 before proceeding to the next section, Filariae: Tissue Nematodes. This review will help you focus on the important details found in this section of the material.

FILARIAE: TISSUE NEMATODES

Table 2-3 lists the scientific and common names for the members of the superfamily Filarioidea (the tissue roundworms) to be discussed in this section.

General Life Cycle

Adult **filariae** live in various human tissue locations. In general, fertilized adult female filariae living in the tissues produce living embryos **(microfilariae)** that migrate into lymphatics, blood, or skin. These parasites require an arthropod **intermediate host** for transmission of infection. If the arthropod ingests microfilariae while taking a blood meal, the larvae molt twice inside the arthropod intermediate host and molt into the infective stage filariform larvae. These larvae are released from the insect's proboscis and enter a new human definitive host when the arthropod next feeds on blood. The entering larvae migrate to the appropriate tissue site and develop to become adults. Maturation can take up to 1 year.

In some species, the microfilariae are more prevalent in peripheral blood at specific times of the day or evening (i.e., they exhibit **periodicity**). These times appear to coincide with the usual feeding pattern of the arthropod intermediate host species. Nocturnal or **diurnal** periodicity is noted in Table 2-4.

At least three other species of filariae are common parasites of humans. *Mansonella perstans*, found in Africa and Central and South America, and *Mansonella*

TABLE 2-3 ■ Filariae

Scientific Name	Common Name
Wuchereria bancrofti (wooch-ur-eer'ee-uh/ban-krof'tye)	Bancroft's filaria
Brugia malayi (broog'ee-uh/may-lay eye)	Malayan filaria
Loa loa (lo'uh/lo'uh)	eyeworm
Onchocerca volvulus (onk'o-sur'kuh/vol'vew-lus)	blinding filaria

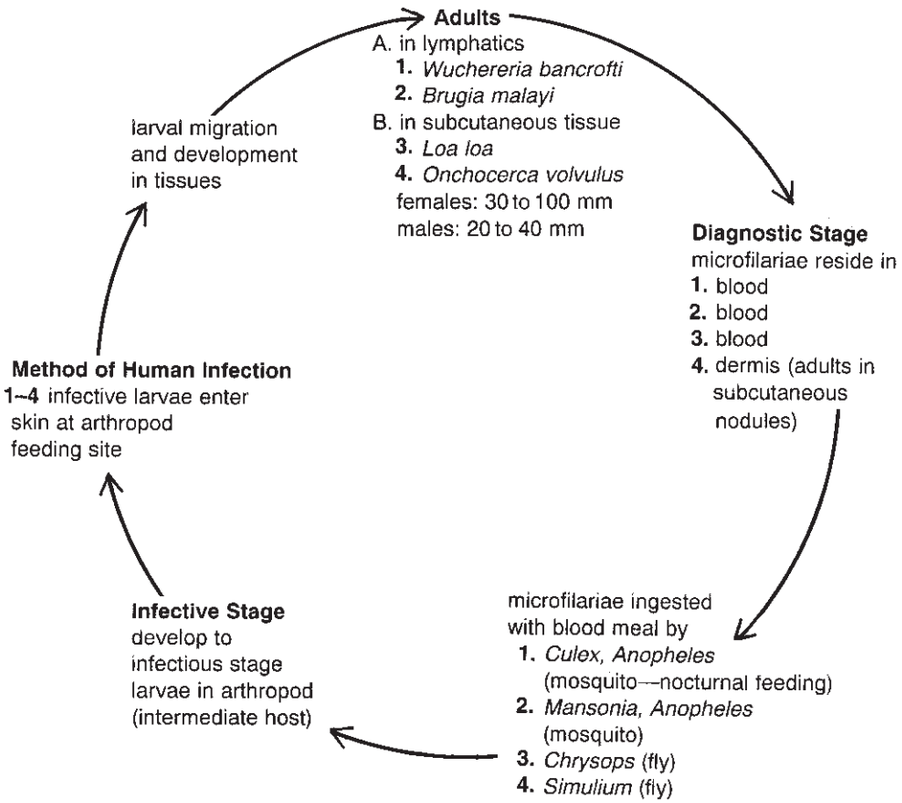
TABLE 2-4 ■ Important Filarial Infections

Scientific and Common Name	Epidemiology, Periodicity, and Intermediate Host	Disease-Producing Form and Its Location in Host	How Infection Occurs	Major Disease Manifestations, Diagnostic Stage, and Specimen of Choice
Wuchereria bancrofti (Bancroft's filaria)	Tropics, nocturnal periodicity, *Culex, Aedes*, and *Anopheles* mosquitoes	Adults live in the lymphatics (microfilariae in blood)	Filariform larvae enter through bite wound into the blood when the mosquito bites a human to take a blood meal	Invades lymphatics and causes granulomatous lesions, chills, fever, eosinophilia, and eventual elephantiasis
Brugia malayi (Malayan filaria)	Far East, nocturnal periodicity, *Anopheles* and *Mansonia* mosquitoes	As for *Wuchereria bancrofti*	As for *Wuchereria bancrofti*	As for *Wuchereria bancrofti*
Loa loa (eyeworm)	Africa, diurnal periodicity, *Chrysops* fly	Adults migrate throughout the subcutaneous tissues (microfilariae in blood)	As for *Wuchereria bancrofti*, except the vector is a bloodsucking fly	Chronic and benign disease; diagnosis: microfilariae in blood; serology; Calabar swelling (a transient, subcutaneous swelling)
Onchocerca volvulus (blinding filaria)	Central America and Africa, no periodicity, *Simulium* (black fly)	Adults live in fibrotic nodules (microfilariae migrate subcutaneously)	As for *Wuchereria bancrofti*, except the vector is a bloodsucking fly	Chronic and nonfatal; allergy to microfilariae causes local symptoms—may cause blindness; diagnosis: adults in excised nodules; microfilariae in skin snips of nodule

ozzardi, found in Central and South America, apparently do not induce pathology but do produce microfilariae in the blood. *Mansonella streptocerca*, found in tropical Africa, produces microfilariae that are found in the skin, as does *Onchocerca volvulus*. Therefore, any microfilariae found in blood or tissue must be differentiated; the diagnostic stages of the species are illustrated to aid in the differential diagnosis of filariasis. Atlas Plates 28 to 33 further illustrate these parasites.

Information on the following pages is keyed by number according to genus and species. These numbers also will be used in the diagrams: **1** = *Wuchereria bancrofti*; **2** = *Brugia malayi*; **3** = *Loa loa*; **4** = *Onchocerca volvulus*.

Filariae



Method of Diagnosis

A. 1.–3. (Numbers refer to organisms in the Filariae life-cycle diagram.) Locate microfilariae (200 to 300 µm) in stained blood smear (see p. 167). Also, you can centrifuge blood samples and lyse red blood cells to concentrate microfilariae in the specimen before staining (see p. 169, Knott technique).

4. Locate microfilariae in skin snips of tissue nodule.

B. Use serology (lacks specificity).

Differentiation of Microfilariae as Seen in a Stained Blood Smear

Examine for the presence or absence of a sheath (a thin, translucent eggshell remnant covering the body of the microfilaria and extending past the head and tail) (Figs. 2-8 and 2-9).

Also, examine the tail area of microfilaria for the presence or absence of cells that exhibit a characteristic array of stained nuclei.

The tail of microfilaria of *Onchocerca volvulus* as seen in a tissue scraping from the nodular mass containing the adult filaria or from a skin snip shows no sheath, nuclei not terminal, and a straight tail.

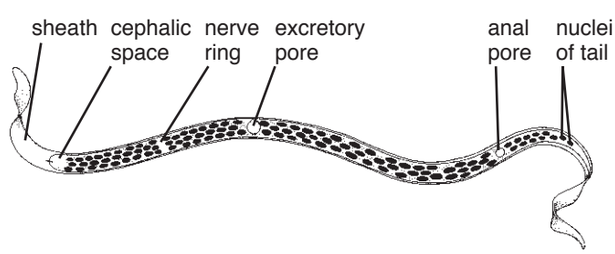


FIGURE 2-8 Structures of the microfilaria.

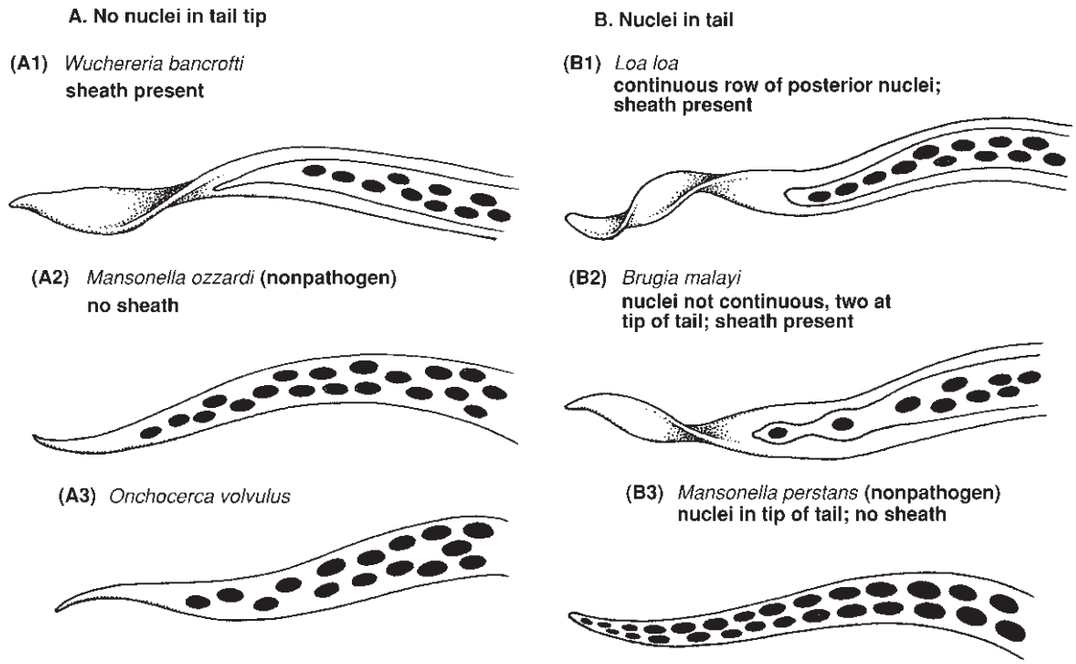


FIGURE 2-9 **A.** Microfilaria species with no nuclei in the tail tip. **B.** Microfilaria species with nuclei in the tail tip.

The tail of *Mansonella streptocerca* microfilaria is bent like a fishhook. These microfilariae are also found in skin snips.

Disease Names

Filariasis (generic)

1. **Elephantiasis**, Bancroft's filariasis
2. Malayan filariasis
3. Eyeworm
4. Blinding filaria; river blindness

Major Pathology and Symptom.

Diagnosis is difficult because symptoms are broad in spectrum. The diagnosis depends on identification of microfilariae.

1.–2. In the early acute phase, fever and lymphangitis are seen; after years of repeated exposure, chronic elephantiasis develops because of obstruction of lymphatics, lymph stasis, and lymphedematous changes. Adults in lymphatics sequentially induce dilation; inflammation; and, after death of the adult worm, a surrounding granulomatous thickening of lymphatic walls. Finally, obstruction and resultant enlargement occur below the blocked area. Malayan filariasis is more often asymptomatic. In endemic areas, "filaria fevers" are seen, with recurrent acute lymphangitis and adenolymphangitis without microfilariae. Also seen is **tropical eosinophilia** or Weingarten's syndrome (which resembles asthma) with high eosinophilia and no microfilariae.

3. Localized subcutaneous edema (Calabar swellings), particularly around the eye, are caused by microfilariae migration and death in capillaries (more serious in visitors to endemic areas). Living adults cause no inflammation; dying adults induce a granulomatous reaction. Proteinuria and endomyocardial fibrosis also occur.

4. Fibrotic nodules on the skin encapsulate adults (onchocercomas). Progressively severe allergic onchodermatitis (pigmented rash) develops; blindness occurs from the presence of microfilariae in all ocular structures (very prevalent in Africa and on Central American coffee plantations).

Treatment

1. Diethylcarbamazine; ivermectin kills microfilariae
2. Diethylcarbamazine
3. Diethylcarbamazine (also prophylactically)
4. Ivermectin

Distribution

1. Distribution is spotty worldwide; it occurs in tropical and subtropical areas.
2. Filariae are found in East and Southeast Asia.
3. They are found in the rainforest belt in Africa.
4. They are found in Central America and equatorial Africa.

Of Note

1. Mosquito resistance to insecticides and coastal-dwelling human populations are increasing the incidence of exposure to infection.
2. Eosinophilic lung (tropical eosinophilia), an asthma-like syndrome, may be caused by occult filariasis or zoonoses.
3. Onchocerciasis is the major cause of blindness in Africa; insect control is difficult because the *Simulium* spp. (intermediate host) breeds in running water.
4. Filarial infection can induce an **immunosuppressed state** in the host that prevents a reaction to the parasite, but immune-mediated inflammatory responses or immunologic hyperreactive immunopathology (elephantiasis response) can still occur.

FOR REVIEW

1. Write the scientific name for each of the following:
   a. Bancroft's filaria: _____
   _____
   b. blinding filaria: _____
   _____
   c. eyeworm: _____
   _____
   d. Malayan filaria: _____
   _____
2. Define periodicity and explain why it is important to know a parasite's periodicity.
   _____
   _____
3. List the general characteristics that must be noted to differentiate the various microfilariae.
   _____
   _____

Review Table 2-4 before proceeding to the next section, Zoonoses. This review will help you focus on the important details found in this section of the material.

ZOONOSES

A zoonosis is a biological life-cycle situation—not a class of parasites. Some parasites that usually live only in animals and survive in "the wild" without any life-cycle need for humans can sometimes infect humans. When this happens, the parasite is living in an unnatural host and will cause symptoms in this accidental host. Many types of parasites cause zoonotic infections, but the nematode group comprises most of the important zoonotic infections seen in humans.

Zoonoses are accidental infections in humans by parasites that usually have other animals as their hosts. Although the animal host and its parasites have evolved together and may tolerate each other well, in an abnormal host, such as a human, the parasite can often cause serious pathology. Table 2-5 lists the scientific names of some nematode zoonotic parasites, their geographic locations, usual animal hosts, disease, and symptoms produced in humans after accidental infection. Although these parasites do not normally complete a full life cycle in humans, it is nevertheless important to study these infections because of the significant pathology they cause in infected individuals.

For example, in the United States, there are large dog and cat pet populations, and these animals commonly have intestinal ascarids (*Toxocara* spp.) and hookworms (*Ancylostoma* spp.). When humans encounter pet feces–contaminated soil, roundworm eggs may be ingested or hookworm larvae may invade exposed skin. Most pet owners do not realize that these dog and cat worms may also infect humans and therefore do not take proper precautions to prevent infections. Small children are particularly at risk because of their play habits (particularly in sandboxes or at public playgrounds) and pica. Various workers (e.g., plumbers, electricians, others who often crawl under raised buildings) and sunbathers sitting on wet beach sand may also be exposed to animal hookworm larvae and are susceptible to larval penetration. Prevention of these infections may be accomplished by monitoring and treating infected pets (especially puppies and kittens) for worms, avoiding potentially contaminated soil, and practicing good hygiene and sanitation. The two main clinical presentations of toxocariasis in humans are visceral larva migrans and ocular larva migrans. Diagnosis is usually made by serology or the finding of larvae in biopsy or autopsy specimens.

Ingested eggs hatch in the intestine, releasing larval forms, which migrate extensively throughout the body. Eventually they become encapsulated in various tissues or organs. Often they are found in the liver, eye, or central nervous system, resulting in organ damage with varying severity depending on the number of

TABLE 2-5 ■ Important Zoonotic Infections

Scientific and Common Name	Geographic Location	Normal Animal Host	Disease	Symptoms in Humans	Method of Infection of Humans
Ancylostoma braziliense; Ancylostoma caninum (dog hookworms)	Southern United States, Central and South America, Africa, Asia, Northern Hemisphere	Dog and cat; dog	Cutaneous larval migrans; creeping eruption	Allergic response of larvae under the skin; red, itchy tracts, usually on legs	Penetration of the skin by filariform larvae
Angiostrongylus cantonensis (rat lungworm)	China, Hawaii, and tropical islands with rats	Rat	Eosinophilic meningoencephalitis	Eosinophilia and symptoms of meningitis; turbid spinal fluid contains many white blood cells, including increased eosinophils (looks like coconut juice)	Ingestion of infected snail or prawn (intermediate host)
Angiostrongylus costaricensis	Central America	Rat		Adult worms lay eggs in mesenteric arteries near cecum, cause granulomas and abdominal inflammation	Eating unwashed vegetables contaminated with mucous secretions from infected slug (intermediate host)
Anisakis spp. (roundworm of marine mammals and fish)	Japan, Netherlands	Herring, other salt-water fish	Eosinophilic granuloma in stomach or small intestine	Abdominal pain and an eosinophilic granuloma around the migrating larvae of *Anisakis* in the intestinal wall	Ingesting raw fish containing the larval stage
Baylisascaris procyonis (Raccoon roundworm)	North America, Europe, Japan	Racoon	Visceral larval migrans (VLM)	Eosinophilia, elevated isohemagglutinins, hepatomegaly, pulmonary inflammation with cough and fever, often history of seizures; alternative to VLM is possible encystment of the larvae in the eye (ocular larval migrans), which mimics a malignant tumor (retinoblastoma); all symptoms result from migration of larvae in the tissues of humans	Ingestion of infective-stage larvae in developed eggs from soil; history of pica in children and exposure to area inhabited by racoons
Capillaria philippinensis	Far East	Fresh and brackish-water fish	Intestinal capillariasis	Malabsorption syndrome, extreme and persistent diarrhea, death from cardiac failure or secondary infection; adults multiply in human intestine and cause blockage	Ingestion of infected raw fish
Dirofilaria spp. (filariae of canines)	Various species worldwide	Dog, raccoon, fox	Tropical eosinophilia, eosinophilic lung	High eosinophilia, chronic cough, pulmonary infiltrates, high levels of IgE; microfilariae are rarely present in peripheral blood	Bite of mosquito vector carrying infective filaria larvae
Gnathostoma spp.	Far East	Dog, cat	Gnathostomiasis	Acute **visceral larval migrans** syndrome, then intermittent chronic subcutaneous swellings; invades nervous system in Southeast Asia	Ingestion of larva from raw, infected fish or application of infected snake poultice to open lesion; larvae migrate into lesion
Gongylonema pulchrum	Worldwide	Pig		Migrating worm in facial subcutaneous tissue	Accidental ingestion of infected roach or dung beetle

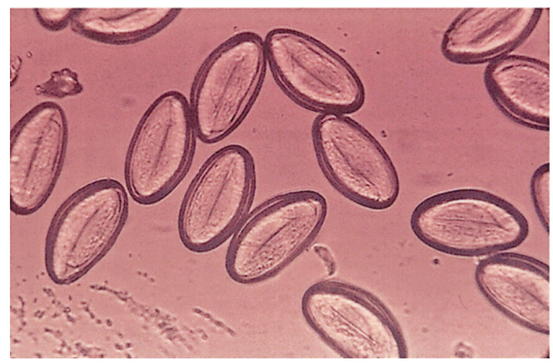
TABLE 2-5 ■ Important Zoonotic Infections—cont'd

Scientific and Common Name	Geographic Location	Normal Animal Host	Disease	Symptoms in Humans	Method of Infection of Humans
Thelazia spp.	Worldwide	Various mammals		Habitation of conjunctival sac or lacrimal duct by adult, severe irritation of eye	Contact with infected fly or roach
Toxocara canis; T. cati (large intestinal roundworms of dogs or cats)	Worldwide	Dog, cat	Visceral larval migrans (VLM) or systemic toxocariasis; ocular toxocariasis	Eosinophilia, elevated isohemagglutinins, hepatomegaly, pulmonary inflammation with cough and fever, often history of seizures; alternative to VLM is possible encystment of the larvae in the eye (ocular larval migrans), which mimics a malignant tumor (retinoblastoma); all symptoms result from migration of larvae in the tissues of humans	Ingestion of infective-stage larvae in developed eggs from soil; history of pica in children and exposure to puppies

larvae and their locations in the host. Blindness and severe brain damage have been associated with larvae of *Baylisascaris procyonis,* an ascarid found in racoons in North America, Europe, and Japan. Cases are rare but are increasing as the raccoon population grows and spreads into urban areas. Eggs are resistant to heat and many chemicals so that contaminated environments are difficult to kill. Incineration of contaminated materials will ensure complete decontamination as will treatment with boiling water or steam; however, 20% bleach does not kill the egg. Awareness of these details will help prevent infection if contaminated materials or soil is encountered.

One final emerging zoonosis in the United States is that caused by *Dirofilaria sp.*, the canine heartworm. This infection is transferred to humans via infected mosquito vectors. Although humans do not exhibit the cardiac symptoms seen in canines, they do suffer with chronic pulmonary symptoms. As infected canine (esp. dogs) populations increase worldwide, the chance for higher human infection rates increase as well. Cases are rare but are slowly increasing. Humans can prevent infection by avoiding exposure to mosquito bites.

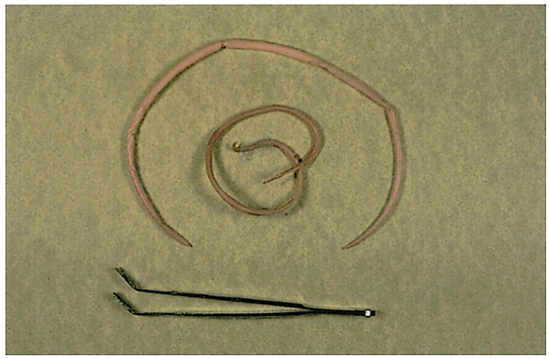
CASE STUDY 2-1



A mother brought her 2-year-old child to the pediatrician to examine a severe rash in the child's anal region. She reported that the child was observed scratching the area repeatedly. The physician performed a cellophane tape test and sent it to the laboratory for analysis. The laboratory scientist noted the parasitic form in the accompanying figure.

1. Was the correct test performed? Why?
2. How is this parasitic infection acquired? How is it maintained within the infected patient?
3. What other parasites may be transmitted with this organism?

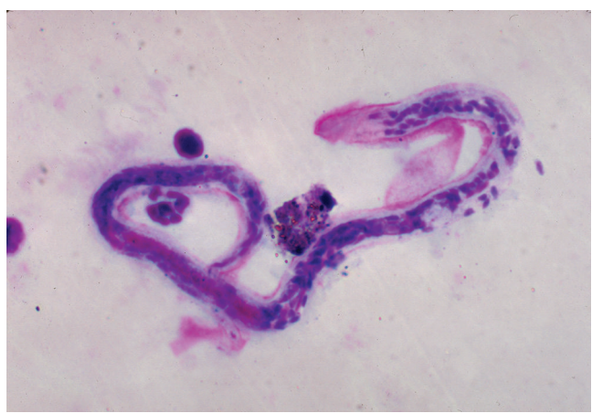
CASE STUDY 2-2



A mother brought the parasite form shown in the accompanying figure to her 5-year-old daughter's pediatrician. She stated that her daughter had been complaining of an upset stomach, had a slight fever, and was having diarrhea "a couple of times" during the last 10 days. Last night, the child vomited this "earthworm" into the toilet.

1. What is the probable identity of this parasite (genus and species)?
2. What other organs are invaded during this parasite's life cycle?
3. What other nematode parasite might commonly be found in patients harboring the worm recovered in this case?
4. What procedure should be performed to rule out other infections?
5. Why did the child vomit out the helminth?

CASE STUDY 2-3



A refugee from Myanmar was screened for admission to the United States. Blood was obtained in the evening. The complete blood count (CBC) indicated mild anemia and the differential report described the form seen in the accompanying figure.

1. What parasite do you suspect (genus and species)?
2. Would this infection be revealed if the resident had his blood drawn first thing in the morning? Explain your answer.
3. What vector(s) are included in this parasite's life cycle?
4. List other clinical symptoms that may be seen in this disease.

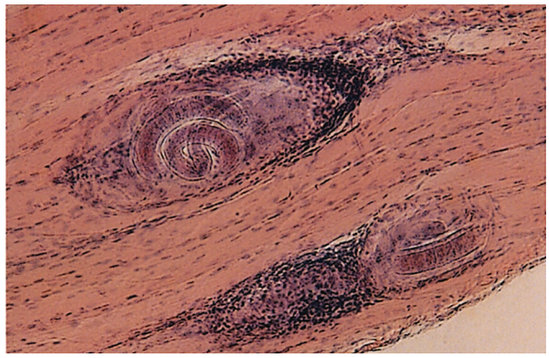
CASE STUDY 2-4

A 62-year-old female from a rural setting visited her doctor presenting with abdominal pain, diarrhea, and peripheral eosinophilia. She stated that over the past winter months she had suffered with several bouts of bronchitis, which was abnormal for her because she was otherwise in good health. Her physician ordered a stool examination for parasites.

The parasite form in the accompanying figure was observed in an iodine-stained preparation from the patient's concentrated sample.

1. What nematode parasites have a lung phase in their life cycle?
2. What parasite (genus and species) do you suspect in this case?
3. Describe the life cycle of this parasite, and explain how it can survive for an extended period in the host.
4. List possible complications that may occur if the patient is not successfully treated.

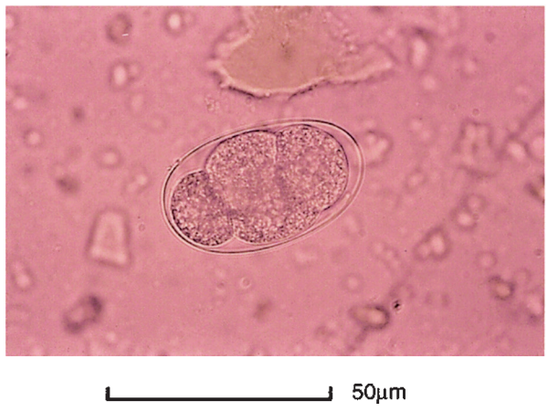
CASE STUDY 2-5



A hunter prepared dried jerky from fresh bear meat and provided some to a group of friends. The hunter and most of his friends developed moderate to severe abdominal pain, nausea, fever, and fatigue within 72 hours. The hunter's physician submitted some of the bear meat for laboratory testing. Laboratory examination of the meat revealed the figure seen above.

1. Based on the patients' symptoms and history, what is the possible parasitic infection (genus and species)?
2. What classic signs are associated with this disease?
3. What other tests should be performed to confirm the diagnosis?
4. What precautions are necessary to prevent infections from this organism?

CASE STUDY 2-6



A 23-year-old female with no documented travel history presented with iron deficiency anemia and periodic abdominal pain. To rule out intestinal infections, a stool sample was sent to the laboratory for culture and parasitic exam. The routine culture results were negative for pathogens. The parasite examination revealed the form seen in the figure above.

1. Based on the patient's symptoms and history, what is the possible parasitic infection (genus and species)?
2. What classic signs are associated with this disease?
3. What must be done to confirm the identity of this parasite?
4. What precautions are necessary to prevent infections from this organism?

You have now completed the chapter covering the Nematoda. After reviewing this material and the related color plates and descriptions in the front of the book, use the learning objectives and review the tables to direct your studies and then proceed to the first post-test. Allow 45 minutes to complete the test. Write your answers on a separate piece of paper. The correct answers are given in the back of the book. If you answer fewer than 80% of the questions correctly, review all the appropriate material and retake the test. Follow this procedure for all chapter post-tests.

➤ POST-TEST

Time: 1 hour

1. Draw the life cycle of *Ascaris lumbricoides* in diagram form. Indicate the diagnostic and infective stages. **(10 points)**

2. The night technician identified the following parasite below: **(15 points)**

   a. What is the scientific name of the parasite?
   b. What is the intermediate host?
   c. In what body specimen was this organism identified, and what laboratory technique was helpful in finding the organism?

3. Briefly define each of the following: **(25 points)**
   a. Cutaneous larval migrans
   b. Diurnal
   c. Diagnostic stage
   d. Infective stage
   e. Prepatent period

4. In which of the following sets of nematodes can each organism cause a pneumonia-like syndrome in

a person exposed to heavy infection with any of the three parasites? **(5 points)**

a. *Ascaris lumbricoides*, *Trichuris trichiura*, or *Onchocerca volvulus*

b. *Enterobius vermicularis*, *Dracunculus medinensis*, or *Trichuris trichiura*

c. *Strongyloides stercoralis*, *Wuchereria bancrofti*, or *Angiostrongylus costaricensis*

d. *Necator americanus*, *Ascaris lumbricoides*, or *Strongyloides stercoralis*

5. A patient presents with vague abdominal pains and a microcytic hypochromic anemia. A possible causative parasite is: **(2 points)**

a. *Enterobius vermicularis*

b. *Ancylostoma duodenale*

c. *Brugia malayi*

d. *Trichinella spiralis*

6. An immunosuppressed patient is susceptible to autoreinfection with which one of the following nematodes? **(2 points)**

a. *Strongyloides stercoralis*

b. *Trichinella spiralis*

c. *Ascaris lumbricoides*

d. *Trichuris trichiura*

7. Infection with *Enterobius vermicularis* is best diagnosed by which one of the following? **(2 points)**

a. Examination of feces for eggs and adults

b. Serology tests

c. Perianal itching noted by patient

d. Examination of a cellophane tape preparation for eggs and adults

8. Human infection with *Loa loa* is best diagnosed by which of the following? **(2 points)**

a. Examination of an infected *Anopheles* mosquito

b. Examination of blood smears

c. Examination of feces

d. Examination of a skin scraping

9. A child who plays in dirt contaminated with human and pet feces is susceptible to which of the following set of parasites? **(5 points)**

a. *Ascaris lumbricoides*, *Trichuris trichiura*, *Trichinella spiralis*, *Wuchereria bancrofti*

b. *Loa loa*, *Capillaria philippinensis*, *Enterobius vermicularis*, *Trichinella spiralis*

c. *Strongyloides stercoralis*, *Toxocara canis*, *Ascaris lumbricoides*, *Necator americanus*

d. *Ancylostoma braziliense*, *Trichuris trichiura*, *Trichinella spiralis*, *Necator americanus*

10. All of the following adult parasites live in the intestinal tract **EXCEPT**: **(2 points)**

a. *Ascaris lumbricoides*

b. *Enterobius vermicularis*

c. *Loa loa*

d. *Trichinella spiralis*

11. The largest adult nematode that is found subcutaneously in infected hosts is: **(2 points)**

a. *Ascaris lumbricoides*

b. *Dracunculus medinensis*

c. *Onchocerca volvulus*

d. *Trichinella spiralis*

12. Each of the following microfilaria has a sheath **EXCEPT**: **(2 points)**

a. *Brugia malayi*

b. *Loa loa*

c. *Mansonella ozzardi*

d. *Wuchereria bancrofti*

13. For each of the following, match the diagnostic technique(s) associated with the given parasite. ***Note:*** **Choices may be used more than once or not at all. (10 points)**

a. Blood film examination	_____	*Ascaris lumbricoides*
b. Cellophane tape test	_____	*Strongyloides stercoralis*
c. Fecal concentration method	_____	*Trichinella spiralis*
d. Tissue biopsy	_____	*Wuchereria bancrofti*
e. Serologic test		

14. For each of the following, match the insect(s) vector found in each filaria's life cycle. ***Note:*** **Choices may be used more than once or not at all. (10 points)**

a. *Anopheles* spp. (mosquito)	_____	*Brugia malayi*
b. *Culex* spp. (mosquito)	_____	*Loa loa*
c. *Mansonia* spp. (mosquito)	_____	*Onchocerca volvulus*
d. *Chrysops* (fly)	_____	*Wuchereria bancrofti*
e. *Simulium* (fly)		

15. Visceral larval migrans is caused by: **(3 points)**

a. *Ascaris lumbricoides*

b. *Ancylostoma braziliense*

c. *Dirofilaria* spp.

d. *Toxocara canis*

16. The zoonotic disease known as creeping eruption is caused by: **(3 points)**

a. *Ascaris lumbricoides*

b. *Ancylostoma braziliense*

c. *Dirofilaria* spp.

d. *Toxocara canis*

CHAPTER 3

Cestoda

LEARNING OBJECTIVES FOR CHAPTER THREE

On completion of this chapter and review of its associated plates as described, you will be able to:

1. State the general characteristics of the phylum Platyhelminthes.
2. Describe the general morphology of an adult cestode.
3. State the methods of diagnosis used to identify cestode infections.
4. Compare and contrast the phylum Nemathelminthes with Platyhelminthes using morphologic criteria.
5. Define terminology specifically related to the **Cestoda**.
6. State the scientific and common names of cestodes that parasitize humans.
7. Describe in graphic form the general life cycle of a cestode.
8. Differentiate adult Cestoda using morphologic criteria.
9. Differentiate larval stages of Cestoda using morphologic criteria, the required intermediate host, or both.
10. Differentiate the diagnostic stages of the Cestoda.
11. Discuss the epidemiology and medical importance of cestode zoonoses.
12. Given illustrations or photographs (or actual specimens if you have had laboratory experience), identify the diagnostic stages of Cestoda and the body specimen of choice to be used for examination of each.
13. Identify the stage in the life cycle of each cestode (including the zoonoses) that can parasitize humans.

GLOSSARY

anaphylaxis (anaphylactic shock). An exaggerated histamine-release reaction by the host's body to foreign proteins, allergens, or other substances; may be fatal.
anorexia. Loss of appetite.
brood capsules. Structures within the daughter cyst in *Echinococcus granulosus* in which many scolices grow. Each scolex can develop into an adult tapeworm in the definitive host.
Cestoda. A class within the phylum Platyhelminthes that includes the tapeworms. These helminths have flattened, ribbonlike, segmented bodies.
copepod. A freshwater crustacean; intermediate host in the life cycle of *Diphyllobothrium latum.*
coracidium. A ciliated hexacanth embryo; *D. latum* eggs develop to this stage and then can hatch in fresh water.
cysticercoid. The larval stage of some tapeworms (e.g., *Hymenolepis nana*); a small, bladder-like structure containing little or no fluid in which the scolex is enclosed.
cysticercus. A thin-walled, fluid-filled, bladder-like cyst that encloses a scolex. Also termed a *bladder worm.* Some larvae develop in this form (e.g., *Taenia* spp.)
embryophore. The shell of *Taenia* spp. eggs and certain other tapeworm eggs as seen in feces.
hermaphroditic. Having both male and female reproductive organs within the same individual. All tapeworms have both sets of reproductive organs in each segment of the adult.
hexacanth embryo. A tapeworm larva having six hooklets (see **oncosphere**).
hydatid cyst. A vesicular structure formed by *E. granulosus* larva in the intermediate host; contains fluid, brood capsules, and daughter cysts in which the scolices of potential tapeworms are formed. Grows slowly and can get quite large.
hydatid sand. Granular material consisting of free scolices, hooklets, daughter cysts, and amorphous material. Found in the fluid of older cysts of *E. granulosus.*
oncosphere. The motile, first-stage larva of certain cestodes; armed with six hooklets (also termed *hexacanth embryo*).
operculum. The lidlike or cap-like cover on certain platyhelminth eggs (e.g., *D. latum*).
parenchyma. Tissue in which the internal organs of platyhelminths are embedded.
plerocercoid. The larval stage in the development of *D. latum* that develops after a freshwater fish ingests the procercoid stage. This form has an immature scolex and is infective if eaten by humans.
procercoid. The larval stage that develops from the **coracidium** of *D. latum.* It develops in the body of a freshwater crustacean.
proglottid (pl. proglottids). One of the segments of a tapeworm. Each proglottid contains male and female reproductive organs when mature.
racemose. Clusters with branching, nodular terminations resembling a bunch of grapes. Used in reference to larval cysticercosis caused by the migration and development of *T. solium* larvae in the brain tissue of humans; an aberrant form.
rostellum. The fleshy, anterior protuberance of the **scolex** of some tapeworms (species specific); may bear a circular row (or rows) of hooks; may be retractable.
scolex (pl. scolices). Anterior end of a tapeworm; attaches to the wall of the intestine of a host by means of suckers and sometimes hooks.
sparganosis. Plerocercoid in human tissue from accidental infection with procercoid of several species of Cestodes.
strobila. Entire body of a tapeworm.
tegument (integument). The body surface of platyhelminths; the Cestode tegument is the site of nutrient and oxygen absorption as well as waste excretion.
transport hosts. Vectors; often bloodsucking insects.
viscera (sing. viscus). Any of the large organs in the interior of any of the three great body cavities of vertebrates.

INTRODUCTION

The Platyhelminthes, as a phylum, are known as the flatworms; they are dorsoventrally flattened and have solid bodies with no body cavity. The internal organs are embedded in tissue called the **parenchyma.** There are no respiratory or blood-vascular systems. The life cycles of these organisms are generally indirect; that is, at least one intermediate host is required to support larval development.

The two classes of the phylum Platyhelminthes that contain human parasites are the Cestoda (the tapeworms) and the Digenea (the Trematodes or flukes). The Digenea are covered in Chapter 4. Platyhelminthes are all **hermaphroditic** with an important exception: the blood flukes.

The external surface (termed the **tegument**) of tapeworms and flukes is highly absorptive and even releases digestive enzymes at its surface from microtriches (specialized microvilli). The adult cestodes must absorb all nutrients through the tegument because this class of parasite has no mouth, digestive tract, or vascular system. Waste products are released through the tegument as well.

Members of the class Cestoda are commonly called *tapeworms,* inasmuch as they are long, ribbonlike, and flattened in cross-section, much like a tape measure. The adult may range from a few millimeters to 20 meters in length, depending on the species.

The adult cestode lives in the intestinal tract of the vertebrate definitive host, whereas the larval stage inhabits tissues of the intermediate host. The anterior end of the adult (termed the *scolex*) is modified for attach-

ment to the intestinal wall of the definitive host. The scolex is usually equipped with four cup-shaped suckers, and some species also have a crown of hooks on the scolex to aid in attachment. A scolex is less than 2 mm long, although the whole tapeworm can be 20 meters in body length. The entire body of an adult tapeworm is termed the **strobila.** The body of the tapeworm consists of segments known as **proglottids.** Segments form by budding from the posterior end of the scolex, an area of germinal tissue for new segment production. Older, mature segments move to the terminal end of the strobila as younger segments are produced.

Each tapeworm is hermaphroditic; that is, every mature proglottid of the body contains both male and female reproductive organs. The reproductive organs in each proglottid mature gradually so that the proglottids toward the terminus of the tapeworm contain fully developed reproductive organs and the uterus is filled with fertilized eggs. The shape of the gravid uterus is distinctive in each species. These posterior segments are termed *gravid proglottids* and can be found singly or in short chains if they break off from the chain and are expelled in feces. The embryo seen within tapeworm eggs (termed the **onchosphere** or **hexacanth embryo**) bears six tiny hooklets that facilitate entry of the embryo into the intestinal mucosa of the intermediate host. After the embryo hatches from the eggshell in the intestine of the intermediate host, it migrates through the intestinal wall and goes to a specific tissue site.

Table 3-1 lists the scientific names (genus and species) and the common names for the cestodes of medical importance. Use the pronunciation guide and repeat each name out loud several times. The life-cycle diagrams of these tapeworms are shown on the following pages, and Table 3-2 reviews the pertinent information about tapeworms. Proceed to the post-test when you have learned the vocabulary and the introductory material, have mastered the life cycles and Atlas Plates 34 to 52, and have reviewed Table 3-2.

TABLE 3-1 ■ Cestoda

Order	Scientific Name	Common Name
Cyclophyllidea	*Hymenolepis nana* (high"men-ol'e-pis/nay'nuh)	Dwarf tapeworm
Cyclophyllidea	*Taenia saginata* (tee'nee-uh/sadj-i-nay'tuh)	Beef tapeworm
Cyclophyllidea	*Taenia solium* (tee'nee-uh/so-lee'um)	Pork tapeworm
Cyclophyllidea	*Echinococcus granulosus* (eh-kigh"no-kock'us/gran-yoo-lo'sus)	Dog tapeworm, hydatid tapeworm
Pseudophyllidea	*Diphyllobothrium latum* (dye-fil"o-both-ree-um/lay'tum)	Broadfish tapeworm

TABLE 3-2 ■ Cestoda Infections

Scientific and Common Name	Epidemiology	Disease-Producing Worm and Its Location in Host	How Human Infection Occurs	Major Disease Manifestations, Diagnostic Stage, and Specimen of Choice
Human Infections with Cestoda				
Hymenolepis nana (dwarf tapeworm)	Worldwide (common in southeastern United States)	Adults live in small intestine	Egg ingested by human in contaminated food or water or hand-to-mouth, autoreinfection is common	Light infections are asymptomatic; heavy worm burdens cause abdominal pain, diarrhea, headaches, dizziness; diagnosis: eggs in feces
Taenia saginata (beef tapeworm)	Cosmopolitan in beef-eating countries	Adult lives in small intestine	*Cysticercus bovis* eaten by human in undercooked beef	Most people are asymptomatic, can experience abdominal pain, diarrhea, and weight loss; diagnosis: eggs or proglottid in feces
Taenia solium (pork tapeworm)	Worldwide (rare in the United States)	Adult lives in small intestine	*Cysticercus cellulosae* larva eaten by human in undercooked pork	Same as *T. saginata*
Diphyllobothrium latum (broadfish tapeworm)	Temperate areas where freshwater fish is eaten undercooked or raw	Adult lives in small intestine	Plerocercoid larva in freshwater fish ingested by humans	Can cause intestinal obstruction and macrocytic anemia because of B_{12} deficiency, abdominal pain, and weight loss; diagnosis: eggs or proglottid in feces

Continued