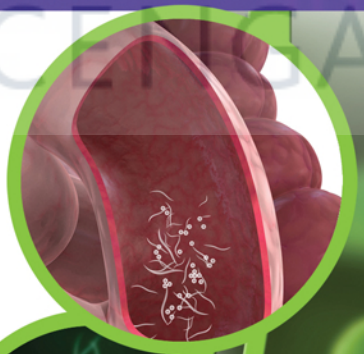
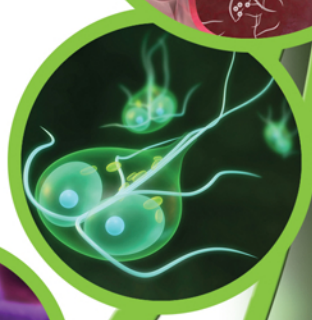
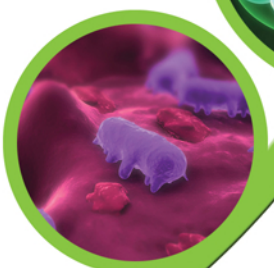
Parasitology for Medical and Clinical Laboratory Professionals







John W. Ridley

Parasitology for Medical and Clinical Laboratory Professionals
John W. Ridley

Vice President, Editorial, Career Education & Training Solutions: Dave Garza

Director of Learning Solutions: Matthew Kane

Senior Acquisitions Editor: Sherry Dickinson

Managing Editor: Marah Bellegarde

Product Manager: Natalie Pashoukos

Editorial Assistant: Anthony Souza

Vice President, Marketing, Career Education & Training Solutions: Jennifer Ann Baker

Marketing Director: Wendy Mapstone

Senior Marketing Manager: Kristin McNary

Marketing Coordinator: Erica Ropitzky

Production Director: Carolyn Miller

Production Manager: Andrew Crouth

Content Project Management: PreMediaGlobal

Senior Art Director: David Arsenault

Library of Congress Control Number: 2011920100

ISBN-13: 978-1-4354-4816-2

ISBN-10: 1-4354-4816-2

Delmar
5 Maxwell Drive
Clifton Park, NY 12065-2919
USA

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

For your course and learning solutions, visit **delmar.cengage.com**

Visit our corporate website at **cengage.com**

Printed in the United States of America
1 2 3 4 5 6 7 15 14 13 12 11

CHAPTER

1

Background of Parasitology

LEARNING OBJECTIVES

Upon completion of this chapter, the learner will be expected to:

- Relate the meaning of the term *parasite*
- Define an organism that qualifies as a parasite
- Describe the importance of hosts in the life cycles of parasites
- Discuss the probable evolution of parasites that infect humans
- List major vectors of parasites and the role they play in causing epidemics
- Define the steps leading to the recovery and identification of most parasites

KEY TERMS

Accidental host
Acquired Immunodeficiency Syndrome (AIDS)
Arthropods
Clade
Commensalism
Congenital
Coproliths
Definitive host
Diagnostic stages
Ectoparasites
Endemic
Eukaryotic
Fleas
Guinea worm
Helminthes
Host
Human Immunodeficiency Virus (HIV)
Infective stage
Infestation
Intermediate host
Kleptoparasitism
Lice
Malaria
Metazoan
Mites
Mutualism
Nematode
Opportunistic
Parasitism
Pathogenic
Phylogenetically
Prions
Protozoa
Reservoir host
Symbiosis
Syndrome
Zoonoses

INTRODUCTION

Parasitology is a diverse and dynamic field that is still evolving as new technology emerges for earlier and more specific diagnosis and treatment of an infection or infection of parasites. The economic toll for parasitosis around the world is staggering, as it impacts human productivity as well as agricultural pursuits of the various areas of the world. A blurring of the distinction of what is considered a parasite exists, and the list includes bacteriology, virology, and mycology (fungi, yeasts, and molds). Parasites are those organisms that use animal and plant species as a host, and some have more than one host, and sometimes includes intermediate hosts that are necessary for continued reproduction and survival of the various parasites.

The parasites found in specific areas may depend upon one specific host or one set of environmental factors that are present in that locale, and are unable to survive in other areas of the world. Therefore, there are endemic areas of the world which are the only geographical regions where certain parasites exist. Some free-living parasites do not require a host in order to survive, but it is believed that parasites and the parasites that require a host greatly outnumber the numbers of free-living species. Parasitism comprises an ecological relationship between two individuals of different species where the parasite's environment is another living organism.

A diverse group of scientists, including ecologists, molecular biologists, immunologists, and biologists, provide a source of information regarding fundamental biological principles of parasitology. The complex relationships involving parasites and hosts aid the students in a variety of medical professions in understanding the interrelationship of a variety of scientific endeavors. The importance of parasites and the human diseases they cause have been known to humans for perhaps thousands of years as archaeological evidence points to this fact. Hundreds of millions of people suffer from malaria and each year over one million human deaths are caused by this parasitic disease. It should be remembered that at one time malaria was somewhat rampant even in the United States. Many species of parasitic worms, blood flukes, tapeworms, hookworms, and ectoparasites such as fleas and lice range from being an annoyance to humans to vector-borne diseases such as bubonic plague and typhus have contributed to large numbers of deaths. Mosquitoes transmit malaria, yellow fever, encephalitis, other viral diseases, and several species of filarial worms. Ticks as vectors carry a number of new and emerging diseases such as Lyme disease that are widely viewed as significant to human health.

The field of public health is closely allied with medical parasitology and expands to a global distribution of parasites that offers challenges in the control of conditions, vectors, and parasites. Public health practitioners are employed on a local basis as well as by state and national agencies. International agencies such as the World Health Organization, private industry, private philanthropic and charitable organizations, and military campaigns are organized to coordinate efforts to control parasitism. Educational facilities also use field exercises around the world to increase the body of knowledge necessary to combat parasitic infections and to train workers and educators in areas where parasites are endemic. It is also important that parasitologists work in agricultural pursuits as malnutrition also contributes to the increase in parasitic infections.

Description of the Meaning of the Word *Parasite*

To understand the word *parasite*, breaking down the word into its parts will go a long way in aiding the learner as he or she goes about the task of learning to identify and to report parasitic infections. The word prefix *–para* has several meanings. For the purposes of this book, the following meanings would be appropriate. *Par*, meaning "equal" or "occurring as a pair" would be the meaning in many cases. In a study of parasitology, however, the prefix would encompass the words meaning "near," "beside," "past," "beyond," or "alongside," same as the prefix for the word *parallel*, indicating two organisms living in tandem with each other. When the word suffix *–ology*, meaning "study," is added to the term *para–*, the almost exact meaning of the entire word *parasitology*, would be a "study of those living closely to each other."

Parasitism is the term used for an existing condition where there is an infection by one or more species of organisms classified as parasite(s). A general statement relating to the classification of parasites is that the parasitic organism cannot live separate from the host as the organism in or upon which the parasite lives or exists. Body sites where the parasite survives will be discussed later in this section. Another useful term employed when discussing parasitism is that of **symbiosis**, which means "living together." Symbiosis is a phenomenon where two or more

organisms that differ **phylogenetically** (term indicating a genetically different lineage) exist over a substantial period of time, although they are completely unrelated. This relationship may be stopped upon the death of one of the organisms, either the parasite or the host.

A number of additional terms are used to describe a parasitic relationship. Symbiosis encompasses **commensalism**, which literally means "eating at the same table," where two organisms co-exist in the same space while one organism benefits but neither helps nor harms the other. The term **mutualism** refers to a condition in which both species derive benefit from the interaction. In the true parasitic **infestation** of humans, the relationship of the organisms is referred to as "parasitism." In this type of relationship, one organism, which is a parasite, is generally the smaller of the two in size. The parasite derives a benefit from the relationship and the other, known as the host, is harmed in some way. Other forms of "social parasitism" exist, such as **kleptoparasitism** and "cheating parasitism," which include relationships between the parasite and the host that are characterized by a less close association between the parasite and a host, however.

What Are Parasites?

Parasites are organisms that are dependent upon a particular species of host the species and may be seen either macroscopically (by the naked eye) or with the aid of a microscope (microscopically). A parasite depends upon the host for its nutrients, and the true parasites obtain their nutrients at the expense of the host. This category of parasite is normally the one which causes **pathogenic** infections of humans. Other relationships found in nature are called *commensual relationships*, where the host and the parasite live in harmony with each other and neither is harmed by the living arrangements and do not cause human parasitosis. A third relationship between a host and the parasite is called *mutualism*, meaning that the host and the parasite both benefit from a relationship with each other. Some parasites of humans cause little or no physical harm, whereas others cause severe disease and death.

The term used for parasites that cause obvious harm is that of *pathogenic*, which is also ascribed to other microorganisms such as viruses and bacteria. Another important term used in parasitology is ***opportunistic***, indicating that the parasite infects those with underlying diseases that predispose them to contract these parasitic infections. Classification of parasites is done by both the anatomical sites in which they are found, and their basic anatomy. For example, **ectoparasites** (such as **lice**) live on the body, whereas other parasites including blood and intestinal parasites live in the body. Descriptive morphology includes the term *worms* (Figure 1-1), which includes several morphological types: **protozoa** (one-celled organisms) and **arthropods** (jointed legs), which also includes either insects and spiders or associated arachnids, many of which are non-parasitic. Some parasitic relationships exist that do not entail an organism living off the nutrients from another living organism. An example of this relationship is a lichen, a fungus which grows on dead wood, a condition that is beneficial in nature for breaking down organic wastes.

Pathogenicity of Parasites

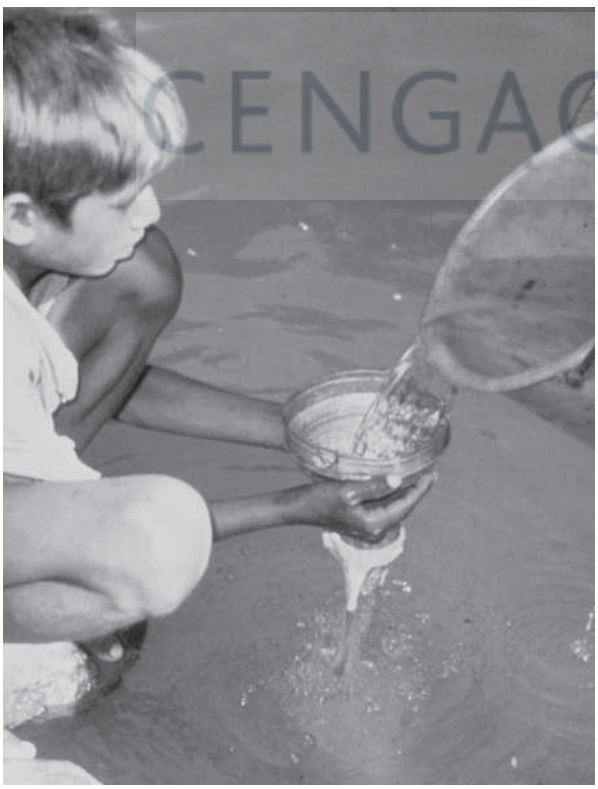
Individual factors greatly affect the outcome for a parasitic infection or infestation. The parasite's size and location of infection, as well as the actual immune response

Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-1 An example of worms as parasites is that of *Ascaris lumbricoides*

the organism stimulates, may either result in physical damage to the host or destruction of the parasite. Or, the infection may result in an absence of symptoms or be only mildly symptomatic. The physical condition of the host and other underlying chronic medical conditions will greatly affect the outcomes of the disease. Some parasites may cause bleeding, irritation of tissues, produce toxins that cause severe reactions, or even obstruct blood vessels or tubular organs of the body. Anemia, organ failure or dysfunction and accompanying bacterial infections and jaundice from destruction of blood or of liver damage may result from significant infections by parasites.

Some parasitic infections are known to have occurred as a **congenital** condition, which means the fetus was infected while in the uterus of the mother. Infections may occur from direct contact with an infected person, poor food hygiene resulting in the ingestion of the organism or its eggs, by vector transmission, or through dirty water (Figure 1-2). Some organisms, such as the hookworm, may penetrate healthy skin and enter the body.



Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-2 Collecting water using strainer to remove vectors for parasites

Other parasites are contracted from living in close proximity with animals which may be the hosts or reservoirs for a large variety of virulent parasites responsible for tremendous human suffering around the world.

IDENTIFICATION OF PARASITES

Along with the morphology and characteristics of the parasitic organism, the eggs of certain parasites are used to identify a variety of parasites, although this is sometimes problematic in that the eggs of more than one species may appear to be essentially the same. Other identifying characteristics include the type of host the organism infects, and sometimes this is used as a common name; that is, Latin terms for the genus and species of the host. Geographic distribution is another important factor, but this is becoming less significant due to worldwide travel and wholesale immigration. Specific climates are often required for propagation of a species in some cases, accounting for some geographic distribution patterns along with the presence of hosts in the immediate surroundings that are suitable as a site in which the parasite can survive and reproduce. Some parasites require vectors to spread the organism to other individual hosts, so this is also a factor in the patterns of distribution. In some cases, certain stages of a parasite's life cycle require a particular species of animal or insect in which to undergo some of the reproductive phases.

HOSTS REQUIRED IN PARASITIC INFECTIONS

The selection of a host by the parasite and its vectors is an important factor in identifying parasites. Most animal species, including humans, are subject to specific parasitic infections by fulfilling at least some of the requirements of the particular parasite in its life cycle. But some parasites, when the conditions are right, may survive in an entirely different species of host than it ordinarily would and some may be found in a variety of species. Some species of potential hosts are naturally immune to certain parasites and this is sometimes true for humans. For example, humans may not contract some of the parasitic infections to which their pets are subject, such as heart worms in dogs. But some investigators have reported rare cases of *Difilaria immitis* the causative organism for heartworm infections in humans, mostly as pulmonary invasions and often by a single worm.

Those individuals who are in good health and practice good hygiene and food preparation safety are less likely to become infected that those who are not careful in their lifestyles and sanitation practices. It has been documented that parasitic infections on a widespread basis occur more frequently in poor and impoverished regions with a low level of sanitation. Parasites also stimulate an immune response when the body produces antibodies against an invasive organism in the same way as with bacterial and viral infections. In many cases, an indirect identification of an organism may be possible by testing for specific antibodies to known organisms.

Three important terms are used in the subject of host descriptions. The main host is called the *definitive host*, and is the organism in which the adult form of the parasite is found. This is a sexually mature form of the parasitic organism. Some parasites require more than one level of host in order to complete a life cycle, which includes maturation and reproduction. An **intermediate host** involves a life cycle where a species of host that differs from that of the definitive host is necessary for competion of the developmental stages of a parasite. An example of this relationship is a widespread type of parasite such as the malarial organism, *Plasmodium vivax*. The intermediate host is the human, where asexual or larval forms of the parasite are found, and the definitive host is a species of mosquito where the parasites undergo sexual reproduction.

Reservoir Host

A **reservoir host** is an organism in which the parasite is harbored until it is transmitted to the main or primary host. The reservoir host may not be harmed extensively or at all while harboring the parasites and is linked to connected populations or environments where a given organism can permanently reside until it is transmitted to a defined target population as a pathogen. Multiple reservoir hosts might exist, and confirmation of the destruction of a reservoir occurs when the target population is free of disease and the parasite has been eliminated. If diseases in the target population are controlled, the presence of a reservoir for the causative organism may never be determined. Practical approaches in identifying reservoirs require field work for identification and effective control of the reservoir hosts.

Reservoir hosts may harbor infectious agents that can infect more than one host species (target population). **Zoonoses** are infections that are common in animals and may also infect humans. These diseases may comprise well over half the bacterial and parasitic infections suffered by humans and the causative organisms number into the hundreds of species. Many livestock pathogens and those that infect domestic carnivores such as dogs and cats may affect multiple host species, including humans (Haydon, Cleaveland, Taylor and Laurenson, 2002).

Accidental Host

Another term sometimes heard when a parasitic infection is experienced is that of **accidental host**. This refers to the infection of an animal or human with a parasite or other organism not normally found in the host. Vectors are also involved in the transmission of many parasites, and may be either biological, such as a mosquito or tick, or mechanical, where the parasites are transmitted by food products or by flies that walk on infected wastes and then pass the parasites from one area to another. Humans may become "accidental" hosts when human infection is not required for propagation and continued survival of the infectious agent found in nature. Most emerging or "new" infectious diseases are zoonotic (animal origin). These zoonotic disease agents may be viruses, bacteria, multicellular parasites or **prions**, the agent associated with "mad cow disease."

TRANSMISSION OF PARASITIC INFECTIONS

The parasitic life cycle is vital in the transmission of parasitic infections. Some parasites spend their entire life cycles in one host, whereas others require more than one host at different developmental stages. Some are parasitic only during periods of development by becoming *free-living* at certain stages. Many parasites also require certain environmental conditions for themselves and their hosts, so many parasites are found in the warmer climates of the world where there is a greater diversity of animal life. Knowledge of the life cycle for suspect organisms is necessary for interrupting the life cycle and thereby minimizing the number of infections, as well as knowing the correct specimen type required for identifying the particular parasite.

The ways humans are infected (modes of transmission) are numerous and often complex. Humans may even infect animals with their own diseases, such as tuberculosis. Animals in which an infectious agent can reproduce with no ill effect on the animal are known as *reservoirs*. Humans come into contact, either directly or

Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-3 Anopheles mosquito, an effective vector of malaria

indirectly, and transmission then occurs with humans as accidental hosts. The arrival of previously unknown zoonotic diseases may correspond with climatic and ecological changes with a resultant movement of pathogens due to the availability of vectors such as mosquitoes (Figure 1-3) and animals that are hosts to pathogens. The spread of diseases may also be facilitated by genetic changes, and adaptation in the pathogens themselves may occur. Changing human behaviors and the inhabiting of areas formerly void of population centers are also contributing factors. It is the author's opinion that the AIDS-causing organism HIV may have infected humans as an accidental host while the reservoir for the organism could be certain species of monkeys and other simians found in tropical areas of the world.

Stages in the parasitic life cycle are important in the transmission of a parasitic organism. A parasite has two stages in its life cycle: the *infective stage* and the *diagnostic stage*. The infective stage is more important in learning the modes of transmission and how to prevent it, and the diagnostic stage is often crucial in properly identifying the organism. Intestinal parasites most often occupy only one stage, a combination diagnostic-infective stage, making identification somewhat simpler.

DIAGNOSIS OF PARASITIC INFECTION

An infestation or infection by parasites in an individual is often difficult to determine, as symptoms may be vague and testing is only partially sensitive in most cases for finding evidence of parasite infection. The term *infestation* usually refers to an ectoparasite, which includes **mites**, lice, and **fleas**, for the most part. The term *infection* refers primarily to parasites that reside within the body of the victim or host. Identification by indirect methodology includes some tests that are based on serological tests, where antibodies produced by an infected person are tested against known organisms (antigens). These methods of diagnosis are becoming more readily available today and may be more sensitive than the current and traditional methods that require a visual and direct identification of pathogens. An advantage of the indirect tests based on the presence of antibodies against an organism is that they may provide positive results and therefore specific identification of the species when only small fragments of antigens, as only parts of the parasite itself, may be present.

However, there are other organisms that require a relationship in which they are required to feed upon a host and are not considered strictly as parasites of the organism they infect. For instance, some multiple parasites feed off the blood of the animal before detaching themselves. Examples of organisms requiring a host upon which to feed in order to maintain life but not themselves classified as parasites are multiple. One of the examples of this type of relationship that benefits only one partner in the process includes the mosquito, which finds nourishment in the blood of warm-blooded mammals such as humans or birds. The mosquito itself is not a parasite, although parasites such as those that cause the disease of **malaria** as well as a few other significant organisms may be transmitted through bites by the mosquito. Other examples of this relationship will be discussed later in this text.

The most predominant type of parasitism in the field of medical parasitology is one in which the term *parasite* is most often used for a **eukaryotic**, pathogenic organism. A eukaryotic organism is one in which the nucleus is quite organized and is contained within a nuclear membrane. Normally, protozoan (unicellular) and **metazoan** (multicellular) infectious agents are classified as parasites, whereas bacteria and viruses are not as they have no organized nucleus. But they do require a host in or on which to live as do the "true" parasites. Interestingly, fungi are not discussed in textbooks of medical parasitology, even though they are eukaryotic and require tissue, either plant or animal depending upon the species, upon which to grow and reproduce. Another topic open for discussion is the blurring of the

distinction between parasitology and tropical medicine, the latter of which includes chiefly bacteria and viruses. Often one will find that all of these studies are conveniently researched by the same organization, such as the World Health Organization, at the same time and in the same location. There will be other references to these practices in this book.

HISTORY OF PARASITES AFFECTING HUMANS

Intestinal parasites most likely have inhabited the gastrointestinal tract of humans since the early beginnings of human habitation of the planet earth. Although it is a rhetorical question, was there a reservoir for the parasites before they infected man? Did they originate early in the history of mankind as part of the normal intestinal organisms that aid in digestion? Or did they possibly function as an aid for stimulating immunity against pathogenic organisms such as some normal bacterial flora now do? A plausible explanation is the possibility that parasites adapted to life in humans after they originated in other animals, with the animal being the reservoir from which humans contracted the organism by eating the meat of the animals or living in close proximity to them. And because intestinal parasites that are similar to those found as pathogens in humans are also found in domesticated dogs and cats as well as in other wild animals, these domesticated animals may have been the original source of parasitic infection (Figure 1-4). And although they differ only slightly for the most part in speciation, these parasites might have specialized for an existence in either man or lower animals from a common obscure origin.

Impact on Human Health by Parasites

Parasites occupy an important position in the history of humans, and are an important part of morbidity and mortality, particularly in the less developed parts of the world. Concurrently with other diseases, medical practitioners are becoming more aware of the possibility of parasitic infections that occur along with, or as a result of, other disease states because a number of parasite species are opportunistic. Anyone who has travelled to a foreign country with poor sanitary conditions for food and human wastes should be evaluated for a parasitic infection, particularly if abdominal bloating or other signs and symptoms arise (Figure 1-5). In addition, migration from those countries where parasites are **endemic** have brought to the shores of the United States and the entire Western world a growing number of heretofore foreign pathogens which have found friendly reservoirs and hosts. Many persons are aware that a health history now almost always questions the patient as to travel within a period of time which might yield clues as to certain infections endemic in some areas of the world. Prior to the United States becoming more advanced and prosperous, humans lived in close proximity with, and had daily contact with, farm animals, so the impact of parasitic infections was much greater in the early history of the United States than it is today.

Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-4 Dogs may have been a source for original parasite infection in man

Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-5 Human wastes and unsanitary conditions lead to infections

Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-6 Female body louse, *Pediculus humanus* var. *corporis*, as it was obtaining a blood-meal from a human host

Although intestinal parasites have received the most attention in modern years, historically the first to receive any attention were those that infected or infested the skin of humans. These ectoparasites were readily visible or at least required immediate attention, due to the discomfort they caused to those infected. The rise of this order of skin parasite or ectoparasite may be used as an example of the manner in which these and other parasites and infectious diseases may travel around the globe. According to current theories on the origins of parasites found to infest the skin of man, it appears that body lice reached the American continents even before early explorers such as the Vikings, who reportedly were the first to reach the North American continent (Figure 1-6). Later, European explorers and possibly the rest of the civilized world, reputedly infected the Native Americans—the North Americans commonly call Indians—along with the Aztecs and Incas. The latter were two indigenous populations that inhabited what is sometimes called the *New World* on both the North and the South American continents. The beginnings of the Aztecs and Indians are even more obscure that those Native American "Indians" we believe had Mongol origins and may have crossed the Behring ice straits between Asia and the western portion of North America.

TRANSFER OF PARASITES FROM ONE AREA OF THE WORLD TO ANOTHER

At any rate, it is believed that the advent of louse infestations predated the Columbian era. This section of the book will use ectoparasites to explain the possibilities for spreading organisms about the world. Just as some larger mammals and other animals are indigenous to one area but eventually are found in a larger geographic region, the spread can best be explained by the example of an ectoparasite, the louse. These organisms are basically the same around the world, but have differing DNA patterns for various populations of lice, with a history of infecting humans since early history.

It was reported in the *New York Times* (2/7, A16, Wilford) that two independent studies detailed in *The Journal of Infectious Diseases* yielded "well-preserved louse DNA" from a pair of Peruvian mummies, remains of two persons who died more than one thousand years ago. This led researchers to the assumption "that lice had accompanied their human hosts in the original peopling of the Americas, possibly as long as 15,000 years ago." This is the length of time that it is commonly believed than man may have inhabited the two American continents. Just as in the example of the louse, certain intestinal parasites are practically the same in diverse parts of the world. But similar parasitic organisms may have different methods of transmission of infection to humans, based on geographic and environmental conditions.

Spread of an Ectoparasite

The example of body lice and the spread of several strains throughout the world provides clues as to how other species of parasites may have spread and evolved. Three strains of lice invade and inhabit the epidermal tissue of humans and are commonly called *clades*. The term **clade** is not specific for any particular species, but refers to a group of organisms that have specific genetic material as a distinct species or strain of a species (some species have more than on strain, i.e., common influenza). This term is dependent somewhat on the anatomical location and particularly the geographic sites where they are found. Some clade A–type lice are found almost everywhere humans, birds, and others live. Clade B–type lice are most common in North America and Europe, indicating that they were transported from one region to another through migrations between continents. Lice from the clade C type are seldom found, as they are quite rare. Some research seems to support that clade B–type lice developed separately and somewhat simultaneously in North and South America, with cross-infections between humans and native fauna found on these continents.

So the best and probably most valid theory is that European settlers brought clade A to the American continents, where they contracted infections of clade B and returned the favor by transporting them to Europe where that continent developed a ready pool of organisms which tended to infect the entire continent. Later study, however, from medical reports from both continents indicated that clade A was possibly also distributed along with B across the Americas hundreds of years before the first Europeans arrived, perhaps by the Vikings and possibly by some Middle Eastern peoples (some evidence exists that Egyptians and others may have crossed the stormy Atlantic in reed ships centuries before the Vikings). The presence of these lice supports a theory that visitors from Europe and other parts of the civilized world came to the New World many years before Columbus. Or, it is reasonable that clade B was prevalent in the early nomads who may have crossed the ice of the Behring Straits thousands of years before the Norsemen came to what they called "Vinland."

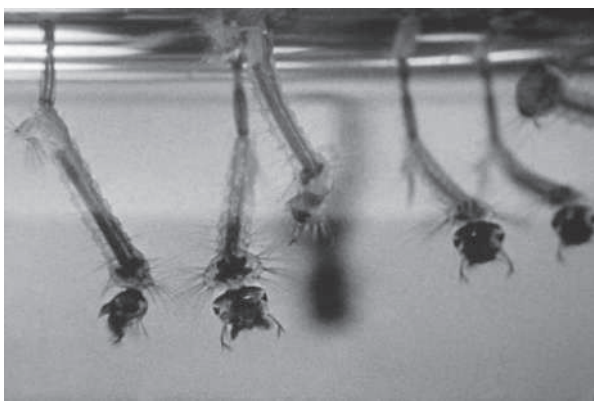
Spread of Intestinal Helminths and Protozoa

During the relatively short history of humans on earth, the species has acquired a substantial number of organisms labeled as parasites. Approximately 300 different species of wormlike organisms, termed as **helminthes**, exist. These species encompass the flatworm, at least half of which are parasites, and includes the tapeworm, an extremely important intestinal parasite of humans. A widely varied form of life, flatworms are also found as marine life and these species are not known to be parasitic. But the species that are parasitic are second only to malaria in exacting a toll on human health.

Currently, more than seventy identified species of protozoa are characterized by appearing as one-celled (unicellular) organisms. Some of these are free-living or inhabitants of the environment and include some of the most important parasitic pathogens of man that are found in the kingdom Protista. This kingdom includes protozoa, uni- and multicellular algae, and slime molds. Ironically, rare occurrences of apparent algal infections among humans have been mentioned. Many of these protozoa are rare and accidental parasites, but humans still harbor a number of relatively common species from which a small percentage cause some of the most celebrated and dangerous parasitic infections in the world. Therefore, this small number that cause serious disease have received the most attention and are targets of worldwide organizations such as the WHO (World Health Organization) that has focused on eliminating them.

Because many of these parasitic diseases occur mainly in the tropics, the field of parasitology has tended to overlap with that of tropical medicine, and it is difficult to separate the two branches as they are inextricably intertwined. In the early part of human civilization, activities necessary for survival may have occurred concurrently with the presence of reservoirs of parasites seeking to find a suitable animal host such as the human to inhabit. It might have been necessary to seek new territory to avoid some of the plagues afflicting mankind and may have actually changed the history of mankind where pockets of dense population have occurred. This would be particularly true where bodies of water necessary for the growth of mosquito larvae to provide efficient vectors exist. Such environments often led to dense populations of the adult mosquito species (Figure 1-7). The Anopheles mosquito is one of the vectors that is capable of transmitting both malaria, a protozoan, and filariasis, a **nematode** (round worms and thread worms), and the *Aedes* species of mosquito is chiefly responsible for inflicting dengue and yellow fever, diseases which are caused by viruses among large groups of victims.

Although the branch of health care called tropical medicine deals mainly with pathogenic strains of bacteria, it is inevitable that the coexistence of bacteria,



Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-7 Photograph of mosquito larvae taken during a 1972 study of disease carriers and pests of migrant labor camps

Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1- 8 Extracting a blood sample from a green monkey

certain strains of virulent viruses, and numerous parasites would be found that are concurrently surviving. All of these would require surveillance and eradication efforts, lending itself to prevention of all of these categories of infectious agents of humans. So our understanding of parasites and parasitic infections cannot be separated from our knowledge of the history of humans and their spread across virtually the entire globe. In particular, the spread and present distribution of many parasites throughout the world has largely been the result of human activities that includes migration and exposure to animals used for food such as the green monkey of Africa, which may be the source of HIV infections in humans (Figure 1-8). The advent of HIV infections leading to AIDS has added a new chapter to the history of parasitology. Those persons who are immunocompromised by an HIV infection as well as by some of the other infectious diseases that impact the immune status are in some manner with a more diverse collection of animals vulnerable to a host of viral, bacterial, and parasitic organisms to which these persons may fall victim.

EARLIEST EVIDENCE OF PARASITIC INFECTIONS IN MAN

As described earlier, the development and subsequent civilization of humans and the advent of parasitic infections appear to have occurred simultaneously. Due to the knowledge gained from the Human Genome Project, where almost all of the genes contained in the human body have been mapped, scientists are now able to learn more about the origins of diseases affecting the human race than was previously possible. And in a similar fashion, historical evidence of organisms that infected the body and the environment are also able to be studied based on findings within the body of mummies and preserved tissue samples and excrement from humans and other animals.

Physical findings exist as records from tens of thousands of years ago apparently exist, where *Homo sapiens* remains have been found in eastern Africa. Eventually these peoples spread throughout the world, moving somewhat in waves, perhaps based on food supplies or disease in certain areas or for other unknown reasons. It is commonly believed by some that about 15,000 years ago, at the end of the Ice Age, humans had migrated to and had sparsely populated virtually the entire world, taking some parasites with them from their previous dwelling sites and becoming infected by others along the way. The human groups of this period may have diversified their holdings of parasites by retaining those that they seemed to have inherited from their primitive ancestors and then picking up others along the way from other animal groups or from the new environments in which they found themselves.

The greater the dimensions of the geographic areas to which human ancestors moved resulted ultimately in contact with a more diverse collection of animals, insects, and plants, along with an increasingly agricultural environment. These migratory patterns left their mark on the humans who had changed their environment through exposure to a panoply of parasites and other one-celled organisms that are related to parasites but cannot truly be called parasites. These souvenirs remained with the groups as they organized into farms and cities and no longer operated as small nomadic groups with little contact from other groups of humans. These cities and settlements, where populations grew denser, were conducive to the facilitation and the transmission of infections between humans.

A somewhat global trade practice began, but, unlike today, it often took years for products of one area to reach another where they might pass through several regions which later became identified as countries. The opening of these trade routes resulted in a much wider dissemination of parasitic infections as well as other species of microorganisms. Groups of people who might have had genetic protection against some diseases were quite vulnerable to others, and those with some natural protection would be similar to what is called "carriers" today.

Then, as civilization advanced, the slave trade most likely began before recorded history and in biblical times. This resulted in indigenous populations that might have been subjugated during war before being transported to unfamiliar areas of the world but living in close proximity to a genetically different population. Around 1500, the Spaniards sometimes enslaved groups of Native Americans as the first in the New World to be enslaved. Then shortly thereafter, African slaves who might have been captured by other tribes and were sold into slavery were transported to the New World, which included the Caribbean islands, from the Old World. More recently the spread of the **Human Immunodeficiency Virus (HIV)**, and the development of **AIDS (Acquired Immunodeficiency Syndrome)** from HIV infections, most likely originated on the African continent. This disease serves to initiate immunodepression associated with these conditions and has spread to the rest of the world in great numbers.

This condition predisposes the person suffering from AIDS to becoming infected with a variety of opportunistic parasitic organisms. It has been proposed and not disproven that this ravaging disease originated in the green monkeys of Africa, as these animals were widely hunted for food, often resulting in contact with the animal's blood and body fluids. It should be kept in mind that the origins of the disease are still in dispute, and has led to various theories over the years since the advent of the disease. The **syndrome** (group of symptoms) of AIDS has resulted in the establishment of a number of new opportunistic parasitic infections that cover the entire globe.

Archaeological Evidence of Parasitic Infections

The past history going back for centuries, and bolstered by archaeological specimens and written records, has confirmed that parasitic infections have a history of infecting humans for as long as any sort of record of humans is available. Much of this information predates written history, with the finding of archaeological specimens that are more ancient than written records. But several thousand years BC, work by ancient Egyptian physicians and then later Greek physicians who wrote of parasitic infections, were recorded. One of the significant areas of the study of parasitology today is that of archaeologists who study the evolution of humans and who have documented the fact that some of the most important parasites we find today, the helminth worms along with their ova and the protozoa, can now be found in ancient preserved stool specimens, lending verification to what was previously only educated guesses or theory.

The presence of helminth eggs and protozoan cysts have been found in preserved stools called **coproliths**, a term that literally means "fecal stones" or remnants of the products of bowel elimination that are stone-like. These fecal samples have become fossilized or desiccated (dried) as they are hundreds and even thousands of years in age. These bits of hardened feces often contained naturally preserved bodies of parasites that had infested the gastrointestinal tract of these ancient peoples. Springing from these studies is a new branch of science called *paleoparasitology*. This helps to extend the knowledge base that previously had been more theory than fact. It is possible that less evolved versions of some parasites seen today may be found in preserved remains of animals and humans and the excrement of each. Examples of some of these discoveries will be discussed later. So vast is the field of human parasitology, and with this new and far-reaching evidence and the discoveries made to date from the past, the amount of data will no doubt grow dramatically in the future.

Written documents related to parasitic infection in ancient Egypt from several thousand years BC exist. Ancient medicine men were apparently aware of parasitic infections, as described in the Ebers papyrus of 1500 BC discovered at Thebes. Somewhat later, Greek physicians in the years from 800 to 300 BC described symptoms and signs of diseases of various descriptions, some of which might have been caused by parasites. Persons with raging fevers, which might have been difficult to control without the medical technology enjoyed today, were found in various works, including those of the celebrated Hippocrates, author of the Hippocratic Oath still in use in differing versions and whose corporate works are known as the *Corpus Hippocratorum*. Other documentation of apparent parasitic maladies are found in ancient works from physicians as members of civilizations other than Greek and Middle Eastern areas.

Although the medical literature of the Middle Ages is quite scant, there are many references to the malady of being infected by parasitic worms. In some cases, they were considered as the primary cause of certain diseases. However, generally the literature of the period was rife with those who were somewhat ignorant due to stultifying

governmental and religious constraints. In Europe, during the Dark and Middle Ages, many retreated into the superstitious beliefs and lack of tolerance by their rulers, instead of continuing the pursuit of knowledge and enlightenment. This period was characterized by strict religious requirements that were mandated by the mostly monarchial governments.

Unlike the periods of the search for knowledge and advancement as found centuries earlier on the Asian continent and the Mediterranean populace, this entrenchment held back medical progress on the European continent during the Middle Ages. But with the advent of the Renaissance period, the augmentation of many cultural accomplishments and scientific advances occurred in a relatively short time. The flurry of activity during this well-documented period eventually led to some of the great discoveries that characterized the end of the nineteenth century and extending into the beginning of the twentieth century. These discoveries were diverse, and included new cultural pursuits, activities by religious organizations, and scientific research. Scientific knowledge expanded to dispel the commonly accepted theory that spontaneous generation occurred in some dirty environments, leading to advances in microbiology.

In the latter part of the nineteenth century, the theory that many diseases were caused by germs, led by Louis Pasteur and others, demonstrated that diseases could be caused by bacteria, and could be prevented by disinfecting areas where medical procedures were performed. The development of a rudimentary microscope by Leeuwenhoek whereby the visualization of bacteria proved the theory that many diseases were caused by living organisms invisible to the naked eye. A technique was also developed to grow colonies of bacteria on nutrient agar in a Petri dish for identification (Figure 1-9). The presence of an organism even smaller than the bacterium was proven in the discovery of viruses by Pierre-Paul Emile Roux, during this time of great achievement and advancement of knowledge. Robert Koch introduced methods of preventing diseases caused by microorganisms, particularly by showing that organisms from an infected site could be grown in animals, producing the disease in them. A number of what are now considered to be medical pioneers made remarkable discoveries in a number of fields. Sometimes working independently, they made mutual findings and then often their ideas fed off each other.

Source: Centers for Disease Control and Prevention (CDC)

FIGURE 1-9 ***Enterobacter cloacae*** **colonial growth 24 hours after being inoculated with a specimen sample**

Sir Patrick Manson, a London physician, is responsible for discoveries in both tropical medicine and parasitology, close cousins of each other. He emphasized the importance of vectors in the transmission of parasites, and worked with others in discovering that a certain species of mosquito was responsible for harboring and transmitting several of the parasitic organisms that still cause untold suffering and in some cases death in the world. Manson returned to London from the Hong Kong College of Medicine in 1890. He participated in the founding of the School of Tropical Medicine at the Albert Dock Seamen's Hospital in 1899 and later taught there. This school is today known as the London School of Hygiene & Tropical Medicine and is an important training ground for all areas of microbiology, including parasitology.

CLASSIFICATION OF PARASITES

The science of helminthology really took off in earnest during the seventeenth and eighteenth centuries following the reemergence of science and scholarship during the Renaissance period. Carl Linnaeus, known as the father of the classification and naming of living organisms,

gave his contribution to science at this time. The term *Linnaean taxonomy* is named for and was devised by Linnaeus and is still largely in use today, although it has changed a great deal since his time. The greatest innovation of Linnaeus, and still the most important aspect of this system, is the general use of binomial nomenclature, the combination of a genus name and a single specific epithet to uniquely identify each species of organism. For example, the human species is uniquely identified by the binomial *Homo sapiens*. No other species of organism can have this dedicated binomial. Prior to the advent of Linnaean taxonomy, animals were classified primarily according to their appendages for locomotion and manner of movement (Niash, 2009).

Because of the importance of and the large size of some helminths, such as the roundworm called *Ascaris* and the tapeworms, it is almost for certain that our earliest ancestors were aware of these common worms. There is some evidence for this assumption based on contemporary studies of primitive tribes in Sarawak and North Borneo, where Dr. Reinhard Hoeppli found that most people are aware of their intestinal roundworms and tapeworms. Hoeppli was best known as a distinguished parasitologist following his service as a German naval physician during the First World War. Some historians have identified references to helminth worms and their diseases in the Bible, but the relevant passages are open to several interpretations. As mentioned previously, the Egyptian medical papyri called the Ebers papyrus, refers to intestinal worms. Again, these records can be validated by the discovery of ossified helminth eggs in mummies dating from 1200 BC.

Also, the Greeks, which again included Hippocrates (460 to 375 BC), knew about the sources of parasitic worms contracted from fishes, domesticated animals, and humans. Following the fall and consequent demise of scientific discovery in the Roman Empire, the focus on medical research and discovery fell to the Arabic physicians. Therefore, some of the names of currently important parasites derive their names from the Arabic influence, including not only the tapeworm but also the **guinea worm**. Many of these discoveries have been recorded in parts of the Arab world, particularly around the Red Sea, for more than a thousand years.

SUMMARY

Parasites have been with animals, including humans, and in some cases plants for the entire history of mankind from the available evidence. Some of the biblical writings of tribulations visited upon humans apparently referred to parasitic infections. Parasites come in many forms, including shapes and sizes, and that impact specific areas of the body and the organs of the body for most species. Parasites can be sufficiently small enough as to require a microscope for identification or as large as helminthes that are capable of growing to several meters in length.

Relationships exist between the parasite and its host, in which the true parasite gains its nourishment from the host. For humans, this strict parasitic relationship is the case in the study of parasites, whereas in nature some parasites and the **host** both benefit from the relationship. In humans, some parasites cause little damage to the host, but some may progress to the point of being fatal to the victim of the infection. Classification of parasites most often depends on the location of the body they infect and their particular type of organism such as amoebae, worms, and insects.

Stages of development of the parasite, and its life cycle, as well as the choice of a host or hosts required for survival and reproduction, are important facets of identification and diagnosis. The main host is called the **definitive host** and in some cases humans are victims as incidental or accidental hosts. For some parasites, a reservoir host is necessary for protecting the parasite until a suitable host, a main host, is available. Basically, a parasite has two life cycle stages: the infective and the **diagnostic stages**. The **infective stage** is the one during which an infection normally occurs, and the diagnostic stage is important for identifying the parasite. Knowledge of the life cycle is important when collecting specimens in order to find the diagnostic stage of development and the likelihood of the highest concentration of parasitic organisms.

The term *infestation* is commonly used for the presence of ectoparasites that parasitize the skin of the body, whereas the term *infection* is used for parasites that colonize the internal organs and body fluids. Identification techniques often include life cycles of parasites

and the geographic location where certain organisms are predominantly found. Methodology for collecting and identifying certain parasites that are found inside the tissues of the body (endoparasites) may require different techniques depending upon the body site where they are found. Some of these organisms may require surgical biopsy of tissue specimens for microscopic examination leading to identification of parasites through special staining of the excised tissues. In these cases where surgical techniques are required, knowledge of the life cycle required for isolating the parasites from bodily fluids and wastes may not be necessary for identification as is the case for most intestinal parasites.

Both diet and recent travel are two areas that are extremely important to the investigator of a probable parasitic infection. Both written records and physical evidence of parasitic infections span the ages, with evidence found in mummified remains from thousands of years ago, but today, efforts are being made to completely rid the world of some of the most virulent parasites. The impact of widespread parasitic infections in the endemic pockets of certain infections is still taking a toll on certain groups of peoples, particularly those with a lack of sanitary options. Worldwide organizations are working tirelessly to reduce or eliminate these serious medical problems areas of parasitic infections but it will require years of effort before substantial inroads are achieved in some areas of the world.

STUDY QUESTIONS

1. What mammals may be subject to parasitic infections?
2. Are other species of living or dead organisms subject to attacks by parasites? Think about the answer to this question.
3. What is meant by natural immunity to parasites? Give an example of a type of natural immunity.
4. What are some conditions that may lead to a greater prevalence of parasitic infections in certain groups of people?
5. Define the following terms:
   Reservoir host –
   Definitive host –
   Intermediate host –
   Accidental host –
6. Name several common vectors of parasites.
7. Why is it important in some cases to know the life cycle of a parasite?
8. When are the two stages of a parasite life cycle both important when performing parasitology procedures?
9. Why are the procedures performed prior to identifying the parasite so important?
10. How is it assumed that some parasites that are similar but perhaps not exactly the same in domestic cats and dogs are also found in humans?
11. Describe how ectoparasite such as the louse (species divided into clades or genetic groups) may be used to trace the migration of humans throughout the world.
12. Label the following organisms by the diseases they primarily transmit or cause:
    Anopheles mosquito –
    Nematode –
    Aedes species of mosquito –
13. How was it determined that parasitic infections have been present for thousands of years?
14. What was the invention that greatly facilitated the beginning of proving the existence of microorganisms, including parasites?
15. What is the term for classifying the nomenclature for the order, family, genus, and species of living organisms?