Parasitism:

The diversity and ecology of animal parasites

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Introduction

You had no right to be born; for you make no use of life. Instead of living for, in, and with yourself, as a reasonable being ought, you seek only to fasten your feebleness on some other person's strength.

Novelist Eliza Reed to her sister, Georgiana in Charlotte Brontë's Jane Eyre

1.1 Parasitism in perspective

To most people, the word 'parasite' conjures up an image of disease and pathology, blood and guts, gross disfigurement, or even death. This notion may be based on some sort of vague imagery suggested by a newspaper article describing mortality caused by malaria or, even more sensational, a graphic television commercial asking for contributions to help victims of 'river blindness'. For the pet owner, it is because of 'parasites' that your veterinarian is likely to ask you to bring a fecal sample (a distasteful task for most!) when you take your pet for its annual checkup. If you are a world traveler, you may be immunized, or must begin taking pills, for one or more parasites, the names of which you never heard before, and may not even be able to pronounce! The physician administering the shots or the pills also is likely to warn you about not drinking the local water, about not eating fresh leafy vegetables, or about cooking meats thoroughly. In all of these instances, parasites of one sort or another are the reasons for the precaution. For the vast segment of the world's population who, live in tropical or subtropical countries, however, many of these parasites are commonplace. It is estimated that >1.4 billion people are currently infected with the roundworm *Ascaris lumbricoides* (Crompton, 1999). Therefore, approximately 20% of the world's population is infected with this one eukaryotic parasite. Three hundred and forty-two helminth parasites have been detected in humans. In addition to *Ascaris*, many of these 342 species also infect hundreds of millions of people, and multiple parasitic infections in a single individual are common. It is, therefore, safe to suggest that over one half of the world's population is infected with a wide range of these beasts! These people live mostly in Third World countries (Table 1.1). Why? For various reasons, but mostly because these folks live in abject poverty, are poorly educated, live where sanitary conditions are poorly developed (if at all) and without access to even the most basic of medicines or medical facilities. Moreover, it is in these tropical and subtropical countries that many of these parasites flourish. Again, why? In the main, it is because parasite diversity seems to be higher in tropical and subtropical areas and because the environmental conditions are conducive to transmitting the parasites that produce these diseases.

Table 1.1 Estimates of current human infections (and distributions) caused by the major parasitic organisms

Disease	Numbers (in millions)	Distribution (primary)
Hookworm	1298	cosmopolitan
Ascariasis	1472	cosmopolitan
Trichuriasis	1050	cosmopolitan
Filariasis	100	Asia; southwest Pacific Islands
Onchocerciasis	18	Central, South America; sub-Saharan Africa
Paragonimiasis	21	Asia; South Africa
Schistosomiasis	200	Asia; Africa
Strongyloidiasis	70	cosmopolitan
Malaria	300	Asia; sub-Saharan Africa; Central and South America
Leishmaniasis	80	Asia; sub-Saharan Africa; Central and South America
Chagas' disease	18	Central and South America
African trypanosomiasis	20	sub-Saharan Africa
Amoebiasis	>500	cosmopolitan
Giardiasis	200	cosmopolitan

Source:
Data from Crompton (1999) and other sources. Some of the infection data for protozoans are updated in Boxes in Chapter 3.
(Modified from Crompton [1999], with permission, *Journal of Parasitology*, **85**, 397–404.)

Parasites are not only common among humans, they are ubiquitous among all plant and animal groups. In fact, various estimates suggest that at least 50% of all plants and animals are parasitic at some stage during their life cycles. This is probably a slight exaggeration, but it is not far from being accurate. In the broadest sense, all viruses, and many bacteria and fungi are parasitic, but traditionally most parasitologists focus on **eukaryotic** animal parasites.

Parasites in humans have been known for thousands of years. Different aspects of their occurrence, cure, and transmission have been of great historical interest (Box 1.1). In the following chapters, we will attempt to provide you with descriptions of some of the most devastating parasites and the diseases they cause in humans and domesticated animals. We also want to stimulate your interest in parasites as biological entities, deserving of study in their own right. Of necessity (because we lack the space in this book), we will restrict our discussion to the more 'conventional' protozoan and metazoan parasites of animals. Throughout, however, we implore you to remember that parasitism is a way of life that transcends all phylogenetic boundaries.

Box 1.1 A brief historical perspective on parasitology and the completion of the first life cycle of a parasitic helminth

Sometime around 1500 BC, an Egyptian physician, or perhaps a group of physicians, assembled a large body of medical information regarding the diagnosis and treatment of diseases known to occur during that period. Written in hieroglyphics on papyrus and sealed in a tomb, it was discovered in 1872, then initially translated by Georg Ebers in 1873; it became known among Egyptologists as the Ebers' Papyrus, an enormously invaluable source that documented the medical profession and various cures used in the ancient world.

Based on these writings, we now know that the early Egyptian physicians were certainly aware of at least two parasitic helminths infecting their patients. One of these was a roundworm, probably *Ascaris;* the recommended treatment for infection by this apparently common parasite included such remedies as turpentine and goose fat, among others. The second parasite was a tapeworm, most likely *Taenia saginata*, for which a special poultice applied to the abdomen was the recommended treatment. Whereas the digenean *Schistosoma haematobium* was not described *per se*, the hematuria (bloody urine) produced by this parasite was well known. Moreover, eggs of this worm have been since identified in mummies from the thirteenth century BC. It is also possible that *Ancylostoma duodenale* was present based on descriptions in the Ebers' Papyrus of a 'deathly pallor' in some patients, a condition that could have been caused by hookworm anemia.

Another group of ancients was equally acquainted with a number of helminth parasites in the fertile Nile Valley at the same time. Thus, for example, consider Numbers 21:6–9, which refers to the Fiery Serpent, now recognized as the nematode *Dracunculus medinensis*. When the Israelites misbehaved during their trek out of Egypt, they were directed by God, through Moses, to 'make a serpent of brass and put it upon a pole'. And, 'when he beheld the serpent of brass, he lived'. This treatment is still used today (see Chapter 5), that is, to remove the parasite from its subcutaneous site of infection, slowly twist the parasite on a stick. Many feel the Hebrew law against eating the flesh of an 'unclean' animal, e.g., a pig, can be traced to a nematode parasite, probably the nematode *Trichinella spiralis*, and maybe even the tapeworm *Taenia solium,* although there is certainly no direct evidence for either suggestion. On the other hand, the Talmud (a sacred Jewish book), written in AD 390, referenced the hydatid cysts of the tapeworm *Echinococcus granulosus*, indicating that they were not fatal.

Periodic fevers due to malaria were mentioned in Chinese writings from around 2700 BC and in virtually every civilization since then. Hippocrates (460–377 BC) provided the earliest detailed description of these periodic fevers. Both Hippocrates and Aristotle (383–322 BC) were aware of 'worms' and refer to cucumber and melon seeds in the 'dung' of humans. Both references are probably to the gravid proglottids of *Taenia saginata*. The word *Taenia* was coined by the Greek writer Pliny (AD 23?–79), and has remained associated with the parasite as the generic name ever since. Galen (AD 130–200) actually referred to the intestinal phases of what were probably *Ascaris lumbricoides* and *Enterobius vermicularis*, saying that the former worms preferred the upper portion of the gut whereas the latter were closer to the anus. Tapeworms, he opined, were found throughout the length of the intestine (the first reference to site specificity by a parasite?).

The gap between Galen's time and the Renaissance, beginning in the thirteenth century, was not a particularly productive period for parasitology in the western world, although the Chinese around AD 200 proclaimed that parasitic worms were created when certain kinds of foods were 'coated with warm blood and nourished by the vital elements of the host'. By the twelfth century, however, the Chinese were on the right track when it was written that humans became infected with worms by 'eating fruits and vegetables or animals' viscera'.

The earliest use of the microscope, by Antony von Leeuwenhoek in the seventeenth century, provided a unique breakthrough for the biological sciences and parasitology. He actually observed, and described, the protozoan parasite *Giardia lamblia* in his own feces. Also in the seventeenth century, a number of other contributions were made through the work of such scholars as Fehr, Spigelius, and Tyson, who prepared detailed drawings of a number of parasitic helminths. The father of modern parasitology was, however, Francesco Redi (1626–1697) who not only determined that mites could make one itch, but apparently was an inveterate collector, dissecting everything in sight and describing some 108 species of parasites in the process. Perhaps Redi's greatest contribution was that he showed that parasites produce eggs, dispelling the widespread myth that parasites developed through spontaneous generation. The idea of spontaneous generation persisted for many years, however, and took Louis Pasteur's now classic experiments in nineteenth-century Paris to quash the notion once and for all.

L. Dufour in 1828 described gregarines from insects and in 1841 G. G. Valentin observed trypanosomes in the blood of fishes. The late nineteenth and early twentieth centuries were times of major discoveries dealing with some of the protozoan and helminth scourges of humans. Patrick Manson in 1878 identified *Wuchereria bancrofti* as the causative agent for elephantiasis and determined that mosquitoes were the insect vectors of the disfiguring disease. Charles Laveran was the first to find the malarial parasite *Plasmodium* sp. in human blood. Ronald Ross, while working in India in 1897, demonstrated that the mosquito was the vector for *Plasmodium*; he was subsequently knighted and won the second Nobel Prize for physiology in 1902. Griffith Evans in 1881 identified the connection between trypanosomes in horse blood and the disease called surra, and David Bruce in 1894 implicated tsetse flies as the vectors for African trypanosomiasis. At the turn of the century, Paul Erlich described the first chemotherapeutic agents for African trypanosomiasis and syphilis. With this discovery, he correctly hypothesized that it should be possible to find organic molecules with selective toxicity to parasitic organisms and, for this, is considered the father of modern chemotherapy. Between 1907 and 1912, Carlos Chagas determined the identity of trypanosomes that cause Chagas' disease and worked out the trypanosome's life cycle in the reduviid intermediate host.

The first recognizable description of the liver fluke *F. hepatica* was in a volume published by Sir Anthony Fitzherbert in 1523. The first published illustration of *F. hepatica* was made by Redi in 1668. With greater use of the microscope inexorably came the development of a radically new concept in biology, the notion of alternation of generation and, with it, the discovery of the complete life cycle of *F. hepatica* by Algernon Phillips Withiel Thomas, a graduate of Balliol College, Oxford. Thomas began his work on the parasite's life cycle in 1880 and had most of it completed by 1883. His work was paralleled by the great German parasitologist, Rudolph Leuckart, who published his version of the parasite's life cycle almost simultaneously with that of Thomas. Both are given credit for this remarkable discovery.

During the winter of 1879–80, liver rot, caused by *F. hepatica*, killed some three million sheep in Great Britain. Seeking a solution to the problem, the Royal Agricultural Society of England approached Thomas who eagerly accepted the challenge. Thomas was not without some insight with respect to the biology of the parasite. For example, cercariae and encysted metacercariae of *F. hepatica* had been described by La Valette St. George in 1855. Subsequently, the German parasitologist David F. Weinland reported in 1875 the finding of what he called 'cercaria-sacs' in the livers of the pulmonate snail *Lymnaea truncatula,* and that the cercariae had a tendency to encyst on inanimate objects. He suggested that the encysted metacercariae on blades of grass could be consumed by grazing sheep, thereby completing the life cycle.

With all of this in mind, in the summer of 1881 Thomas located an appropriate study area where sheep losses had been high the previous winter. He next found *Lymnaea truncatula* in a marsh and discovered rediae in the livers of the snails. He was on the right track for making the discovery. As luck would have it though, in the summer of 1882 he could not find any snails. He believed, however, that their disappearance was correlated with the absence of liver rot in sheep during the previous winter. The following summer brought local flooding and the return of his snails. His initial inclination was to obtain encysted metacercariae and use them to infect rabbits. Thomas, however, decided to focus his efforts on the first part of the life cycle. So, he obtained adult parasites from infected sheep and then eggs. He incubated the eggs which subsequently hatched, releasing what he termed 'embryos'. He was intensely fascinated with this part of the cycle, describing in great detail the swimming behavior of the 'embryos', their penetration into the snails, and their subsequent intramolluscan development. He made these and a number of other highly significant observations, with the almost complete description of the cycle being published in the *Quarterly Journal of Microscopical Science* in January, 1883. The one thing he did not do, however, was to expose any experimental animals to the metacercariae. Unfortunately, his work on *F. hepatica* came to a close when he moved to New Zealand where he taught and, alas, became an academic administrator. Several months before his death in 1937, at the age of 80, he was knighted for his many contributions in the field of education.

The next to the last step in solving the problem of the enigmatic life cycle was made in Hawaii by Adolpho Lutz in 1893 who succeeded in infecting several guinea pigs, a rabbit, a goat, and a brown rat with the parasite, although J. E. Alicata later asserted that Lutz was working with *Fasciola gigantica* and not *F. hepatica*. The final step was taken by D. F. Sinitsin, the famous Russian parasitologist, who early in his career worked at Shanjasky University in Moscow before being forced by the Russian revolution into fleeing to the United States in 1923. Sinitsin in 1914 proved that, upon excysting in the gut of the definitive host, the parasite actually penetrated the intestinal wall and migrated via the liver to its final resting place in the bile ducts and gall bladder rather than directly from the lumen of the intestine into the bile ducts as was believed by Leuckart.

The history of parasitology is a fascinating one, filled with mysteries solved and new mysteries created by their resolution. But this is the nature of science itself, isn't it? By answering old questions, new ones should always be discovered. Thomas and Leuckart will be remembered primarily for their solving a great scientific mystery but, in doing so, they and their pioneering contemporaries pointed the way for all those who followed, and succeeded, in resolving so many other parasitological mysteries.

1.2 Symbiotic relationships

Parasitology is the science that deals with one of several different kinds of symbiotic relationships. We would be remiss if we did not provide you with a definition of a parasite, at least to the extent that conventional wisdom dictates, i.e., the dreaded dictionary definition. According to the 2nd Edition of the *Oxford English Dictionary*, a parasite is:

> An animal or plant which lives in or upon another organism (technically called its host) and draws its nutrients directly from it. Also extended to animals or plants that live as tenants of others, but not at their expense (strictly called commensal or symbiotic); also to those which depend on others in various ways for sustenance, as the cuckoo, the skua-gull etc.

Webster's Third New International Dictionary of the English Language invokes directly the concept of harm:

> An organism living in or on another living organism obtaining from it part or all of its organic nutrient, and commonly exhibiting some degree of adaptive structural modification – such an organism that causes some degree of real damage to its host.

Perhaps useful to some, these definitions define a word, but tell us little about the concept of parasitism. We suspect that if you assemble 10 scientists and ask them to define parasitism, you would obtain 10 different answers. Our approach to parasitism in this book is decidedly ecological and we favor treating the subject as one of several, broad and often overlapping classes of symbiotic relationships. We consider symbiosis to mean, simply, organisms living together. In this case, there is no implication with respect to the length or outcome of the relationship, or the degree of adaptation.

Given such a broad definition of symbiosis, a functional separation can be made in terms of trophic relationships and then, if and how energy is transferred between symbiotic organisms. Such categories should best be viewed as a continuum, with vague boundaries (Fig. 1.1); some consider such a continuum as a broad trend in evolution.

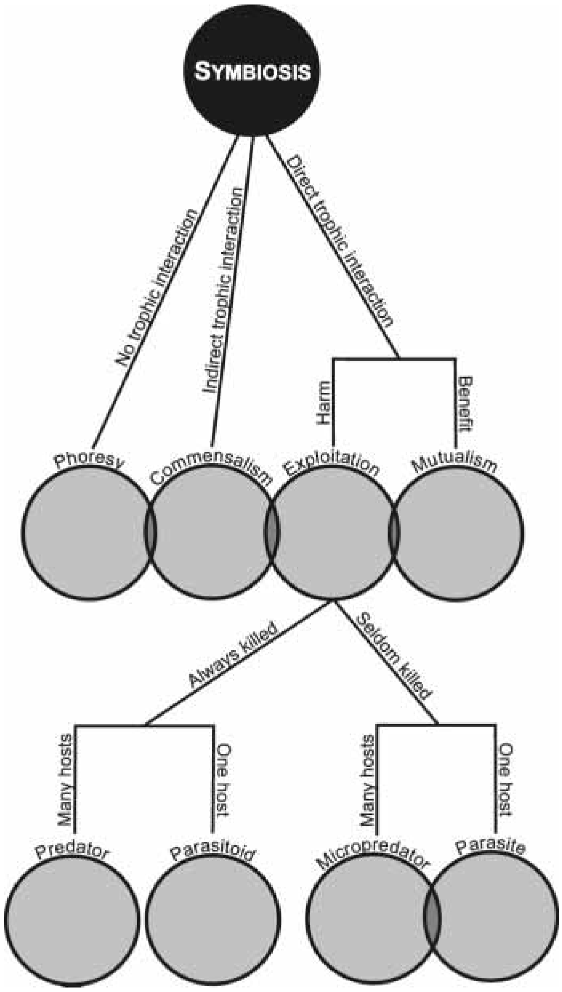

Fig. 1.1 An attempt to find 'parasitism's place' within the context of symbiotic relationships. This is only one way of looking at parasitism and it is based, initially, on trophic relationships, followed by 'harm', and finally, quantity of hosts involved. The final criterion, number of hosts attacked, is meaningful only if restricted to a single life-history stage. For example, adult parasitoids may attack many prey but their larvae live in, and consume, only a single individual. Likewise, a typical helminth parasite may have both intermediate and definitive hosts but each life-history stage will infect only a single host individual. We cannot emphasize too strongly that the overlap between many of the relationships reflects the extraordinary diversity of life styles found in nature. Seldom, if ever, can one classify a group of organisms exclusively.

As we note above, there are many views on parasites, and Fig. 1.1 should provide a point of discussion for a parasitology class. For example, one might consider separating life styles based on immunological interactions, or suggest that there are but two fundamental life styles, e.g., parasitic (a 'host' is involved) versus free-living (no 'host' is involved).

If there is no trophic interaction between the organisms in the symbiotic relationship, then the relationship is called phoresy (Fig. 1.1). The process of pollination is an excellent example. When a butterfly obtains nectar from a flower, it will become dusted with pollen and then, when it moves to the next flower, pollen is carried with it ensuring fertilization of the second flower. There is, however, no trophic interaction or transfer of energy associated with the interaction between the butterfly and the pollen.

Phoresy grades into commensalism, a symbiosis in which there is a trophic relationship and a transfer of energy between the symbionts (Fig. 1.1). The benefit gained is unidirectional, one partner benefits and the other is neither harmed nor helped. A frequently cited example is the relationship between sharks and remoras. When sharks feed on large prey, they scatter pieces of flesh. Remoras feed on these scraps, thus deriving energy from the actions of the host even though the transfer of energy is indirect.

When there is a direct transfer of energy between the partners, the interaction may be either mutualistic or exploitative (Fig. 1.1). In a mutualistic relationship, both symbionts not only obtain benefit, but neither can survive without the other. Lichens are a classic example of an obligate association between a fungus and an alga. In this case, the fungus provides protection and moisture for the alga and the alga in turn provides nutrients for the fungus. Similar relationships are thought to exist between algae and many of the coral reef-forming cnidarians. The relationship between ruminants and the microorganisms in their stomach is also mutualistic. On the one hand, the ruminant host provides an almost continuous supply of carbohydrate in the form of cellulose, plus an otherwise constant environment. On the other hand, the rumen-dwelling microorganisms secrete enzymes that convert the cellulose into glucose. The rumen-dwelling symbiotic organisms first use these glucose molecules as an energy source. Living in an **anaerobic** environment means that the intermediary carbohydrate metabolism of the microorganisms is inefficient (see Chapter 2). The end products of glucose degradation by these symbionts include mostly short-chain fatty acids. Even though these fatty acids are metabolic 'waste' products from the microorganisms, they still possess substantial levels of potential energy. The ruminant absorbs the fatty acids in its intestine, transports them to the liver, and converts them into glucose. The converted glucose is then used as an energy source by the ruminant in the same way other mammals use it. The complexity of this mutualistic arrangement is obvious and clearly is the product of a long evolutionary history.

In most exploitative interactions, however, benefit is in one direction and, moreover, some form of disadvantage, or harm, is the outcome for the other partner. Several major categories of this kind of exploitation can be recognized based primarily on the number of hosts attacked by the symbiont and the subsequent fate of the organism assaulted (Fig. 1.1). If more than one organism is attacked, but typically not killed, then the aggressor is called a micropredator. Hematophagous organisms such as mosquitoes, and some leeches and biting flies, for example, are highly successful micropredators. If more than one organism is attacked and always killed, then the aggressor is considered a **predator** (predatory relationships should need no further elaboration!). If only one host is attacked and is always killed, then the aggressor is usually referred to as a parasitoid, most of which are hymenopterans and dipterans. For example, an adult female wasp may deposit her egg(s) on, or into, an insect. On hatching, the larval parasitoid will consume the host, killing it in the process. Finally, if only one host is attacked, but typically is not killed, the aggressor is a parasite. Indeed, remember that our human attempts to categorize relationships may often be inadequate. For example, as we have suggested above, parasitism denotes some 'harm' to the host. Frankly, most of the time that is true. Interestingly, however, there are a few experimental studies that show potential benefits to being parasitized (e.g., Lincicombe, 1971; Munger & Holmes, 1988). In fact, unlikely as it may seem, many years ago *Plasmodium* infections were used as a control for syphilis and the rarity of tertiary syphilis in Africa is thought to be due to the high prevalence of malaria (Garnham, 1981).

1.3 Kinds of parasites

Endoparasites include those parasites that are confined within the host's body. They include the more familiar animal parasites such as protozoans, digeneans, cestodes, nematodes, and acanthocephalans. Many bacteria and all viruses are also endoparasitic. Parasites typically confined to the exterior of the host's body are called **ectoparasites**. Most parasitic arthropods and most monogeneans are ectoparasitic.

Another dichotomous method for classifying parasites is based on their size. Generally, **macroparasites** are large and can be viewed without the aid of a microscope. They can be endoparasitic, such as digeneans, cestodes, nematodes, and acanthocephalans, or ectoparasitic, such as arthropods and monogeneans. **Microparasites**, as their name implies, are mostly microscopic and can be ectoparasitic or endoparasitic. They may also be intracellular, or extracellular, or both. Eukaryotic microparasites are primarily protozoans.

Most **obligate parasites** are parasitic as adults. The larvae of these organisms, however, may include both obligatory parasitic forms and/or free-living stages. The adults of some species are commonly free-living but, should the opportunity be presented, their progeny may become parasitic. These organisms, mostly protozoans, and a few nematodes and isopods, are referred to as **facultative parasites**.

Parasites can have parasites too. These parasites of parasites are called **hyperparasites**. Hyperparasitism appears to be much more common than was once believed. Due to their small size, some hyperparasites may have been overlooked. Hyperparasites are usually bacteria or viruses, but some protozoans, cestodes and crustaceans have been found parasitizing other parasites.

1.4 Kinds of hosts

The organism in, or on, which a parasite reaches sexual maturity is the **definitive host**. Some parasites require only one host to complete their life cycles. These cycles are said to be **direct life cycles**. All monogeneans, and some nematodes and arthropods, have direct life cycles. Many animal parasites, however, have obligate **intermediate hosts** in which the parasites undergo some developmental and morphological change, but do not reach sexual maturity (there are several exceptions, i.e., progenesis and neoteny, but discussion of these patterns will be deferred to subsequent chapters). Life cycles in which more than one host is required are **indirect life cycles**.

Some protozoans and filarial worms employ **vectors** as hosts. Vectors are micropredators that transmit infections from one host to another. A vector may be an intermediate or a definitive host, depending on whether the sexual phase of the parasite's life cycle occurs in it or not. Being a vector implies a more active role in transmission rather than a passive one. For example, the insect vectors for species of *Plasmodium,* the causative agents of malaria, are female mosquitoes that actively inoculate infective agents of the parasite into the vertebrate host during their blood meal.

A number of parasites may employ hosts in which there is no development and that are not always obligatory for the completion of a parasite's life cycle. These are called **paratenic** or **transport hosts**. Such hosts are most frequently used to bridge an ecological, or trophic, gap. For example, a parasite may require an ostracod as a second intermediate host and a frog as the definitive host. Under normal conditions, frogs do not prey on ostracods, but they do consume odonate naiads which feed on ostracods. The parasite may be transferred from an ostracod to the naiad, then to a frog definitive host. Its chances for reaching the frog host are thereby immeasurably increased by bridging the trophic gap between the ostracod and frog hosts. Ecologically, transport or paratenic hosts are important because they may help disseminate the infective stages of the parasite, or they may aid these stages in avoiding unfavorable conditions such as the temporary absence of a definitive host.

A number of animals are normal hosts for parasites that may also infect humans. These are called **reservoir hosts**. Ecologically they are similar to transport or paratenic hosts since they may keep the parasite from becoming locally extinct when the natural host is unavailable. These parasites, because of their normal associations with animals in nature, are particularly difficult to control.

1.5 Ecology and the host–parasite relationship

As we will emphasize throughout this book, the essence of parasitism rests with the nature of host–parasite relationships. If we accept the simple definition of ecology as the study of the relationships between organisms and their environment, then it is not difficult to understand why parasitism is an ecological concept. Ecologically, however, the host–parasite relationship is a 'double-edged sword'. This is because in dealing with parasites and their hosts from an ecological perspective, one must simultaneously consider the ecology of the host(s) in a parasite's life cycle, as well as the host as a habitat for the parasite. Many of the biotic and abiotic vagaries affecting the ecology of the host will also affect the parasite. But the parasite also must deal with a host that is alive, and capable of responding physiologically and immunologically to the parasite. It must be understood that these latter interactions between the parasite and the host are as 'ecological' as those involving the host's relationships with its own environment.

The study of parasitism, whether from an ecological or physiological perspective, is a fascinating exploration of organisms that make their living at the expense of others. We hope that you will enjoy this brief exploration and that it will serve to stimulate you to learn more about these fascinating creatures. To that end, we provide Box 1.2, which, current at the time of writing this book, provides a number of web sites about parasites. If you continue on in the sciences, no matter what discipline, remember parasites. They can often prove useful for addressing a variety of questions and hypotheses. If your future is not in science, remember parasites anyway – they make extraordinary dinner conversation!

Box 1.2 Parasitology in cyberspace

Even though we believe that nothing can replace the warm feeling of printed information, the Internet is a vast and, often, very useful resource. Here, we provide a list of websites current at the time of the writing of this book. Some sites focus on specific information about parasites, others are photographic galleries with outstanding images, still others provide excellent links to other sites of parasitological interest. An exhaustive listing is nearly impossible and highly redundant. Surfing is inevitable.

http://asp.unl.edu
Official website of the American Society of Parasitologists. Offers information about the society and its activities as well as links to relevant parasitological sites.

http://www.parasitology.org.uk
Official website of the British Society for Parasitology. Offers information about the society and its activities as well as links to relevant parasitological sites.

http://dspace.dial.pipex.com/town/plaza/aan18/urls.htm
Excellent website created and maintained by Dr. David Gibson at the Natural History Museum of London. It provides an exhaustive list of parasitological URLs taken from a poster on Internet Resources presented at a meeting of the

British Society for Parasitology. This list is updated regularly and includes more than 400 URLs. This website provides links to sites with information about parasites, parasitological societies, parasitological resources, images, newsgroups, journals, books, people, courses, meetings, etc. A great surfing site.

http://www.dpd.cdc.gov/dpdx/
Useful site for the identification and diagnosis of parasites of public health concern. It provides information about life cycle, geographical distribution, clinical features, diagnosis and treatment for each of the parasites listed. It also includes a Parasite Image Gallery.

http://www.biosci.ohio-state.edu/~parasite/home.html
Very useful website maintained by Dr. Peter Pappas at Ohio State University. It is aptly called Parasites and Parasitological Resources.

http://www.ksu.edu/parasitology
Website about *Cryptosporidium* and Coccidial Research at Kansas State University. It contains relevant, up-to-date information about these parasites as well as a nice image tutorial to test our knowledge of parasites. It also provides links to the source of the images used in the tutorial.

http://www.cvm.okstate.edu/~users/jcfox/htdocs/clinpara/Index.htm
Website of Veterinary Clinical Parasitology Images created by Professor J. Carl Fox of Oklahoma State University. An excellent site with images, keys, and other interesting features about parasites.

http://www.ag.arizona.edu/tree
This website is called the Tree of Life. It is a multi-authored Internet site containing information about phylogeny and biodiversity. The information is linked together in the form of and evolutionary tree connecting all organisms to each other. The site is changing constantly as new information is added. Look for your favorite parasite!

http://www.parasitology.org
Website of Veterinary Parasitology at the University of Missouri. The site includes lecture notes from a parasitology course, as well as images, diagnosis information, and even a glossary of terms used in parasitology.

http://www.riaes.org/resources/ticklab/
Website of the Tick Research Laboratory, which is devoted to the study of various aspects of tick-borne diseases. The site provides detailed information about tick-borne diseases as well as images of ticks.

http://parasite.biology.uiowa.edu
This website contains 2320 images and information about parasites taken from Dr. Herman Zaiman's publication 'A Pictorial Presentation of Parasites'. Although the site is password protected, everyone can access it by using the user name 'guest' and the password 'visitor'.

http://parasitology.icb2.usp.br/marcelocp/
Website with many good original images of parasitic insects, ticks and mites.

http://cal.vet.upenn.edu/
Website of the University of Pennsylvania, School of Veterinary Medicine, Computer-Aided Learning Project. Follow the shortcuts to 'Diagnosis of Veterinary Endoparasitic Infections' (**http://cal.vet.upenn.edu/dxendopar/**), 'Parasitology' (**http://cal.vet.upenn.edu/parasit/P_index.html**), and 'Parasitology Course 4001: Laboratory Demonstrations' (**http://cal.vet.upenn.edu/paralab/index.html**). These sites provide lecture notes, images, and diagnostic procedures for parasites.

http://www.medicalweb.it/aumi/echinonet/
An online newsletter of the WHO Informal Working Group on Echinococcosis. The website belongs to the Tropical Diseases Web Ring, a network of websites dedicated to tropical diseases, all of which include original information and regular updates. Once the user logs into one of the sites in the Ring, he/she can go to all the other sites included in the ring just by clicking on a single icon in the web page.

http://info.dom.uab.edu/geomed/index.html
Site of the Division of Geographic Medicine of the University of Alabama at Birmingham. It offers information about traveler's medicine and links to other websites.

News:bionet.parasitology
Access to a parasitology newsgroup.

http://www.cdc.gov/
Home page of the Centers for Disease Control.

http://www.who.ch/
Home page of the World Health Organization. Of special interest is **http://www.who.int/ctd**, which is the WHO Division of Control of Tropical Diseases. It includes good updates on tropical diseases caused by parasites.

http://www.mic.ki.se/Diseases/c3.html
Website of the Karolinska Institutet, a prestigious medical facility in Sweden. Offers organized links to numerous websites of interest for parasitologists, some of which are little known but interesting.

http://www.nhm.ac.uk/
Website of the Natural History Museum, London. The search engine of the site provides access to parasitological information.

http://www.iss.it/
Istituto Superiore di Sanità. Italian counterpart of the Centers for Disease Control.

http://www.pasteur.fr/
Home Page of the Institut Pasteur in France. Offers links to areas of interest.

http://www.lshtm.ac.uk
Home page of the London School of Hygiene and Tropical Medicine.

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