

CONTENTS

CHAPTER 1 AN INTRODUCTION TO PARASITISM

1.1 BUILDING AN UNDERSTANDING OF THE BASICS OF PARASITISM

Parasites live in or on their hosts and cause them harm

Opinions vary on how to define some of the key aspects of parasites and their biology

The residence time for a parasite in or on a host is highly variable

There are many additional ways to categorize parasites

1.2 HOSTS—ESSENTIAL LIFELINES FOR PARASITES

Hosts also fall into several different categories

1.3 APPRECIATING PARASITISM'S PLACE IN NATURE

Parasitism is one of several categories of symbiotic associations

Parasitoids straddle the boundary between predation and parasitism

Our understanding of parasitism is enhanced by an appreciation of its relationship to another ubiquitous type of symbiosis, mutualism

REVIEW QUESTIONS

REFERENCES

CHAPTER 2 AN OVERVIEW OF PARASITE DIVERSITY

2.1 THE DIVERSITY OF PARASITE SPECIES

What constitutes a parasite species requires some explanation

Given these considerations, how many species of parasites inhabit the Earth?

Evolutionary trees are used to visualize evolutionary relationships and to display parasite diversity

Efforts are well underway to reveal the overall tree of life

1	Horizontal gene transfer (HGT) has been pervasive throughout the evolution of life	29
	Many bacteria are parasites	29
2	Eukaryotes are a very diverse group that includes many different kinds of parasites	30
2	HGT has also played a role in the evolution of eukaryotic parasites	34
4	The Apicomplexa is a huge, important, nearly exclusive parasitic group of organisms	35
6	Many well-known parasites belong to familiar groups of multicellular organisms	37
	2.2 INSIGHTS INTO PARASITISM FROM THE STUDY OF DIVERSITY	46
9	The phylogenetic affinities of enigmatic parasites can be revealed	46
9	Some groups of parasites remain “persistent problematica”	48
12	Studies of parasite diversity reveal how particular parasites came to infect humans	49
12	Studies of diversity can help reconstruct the historical biogeography of parasites	52
13		
	2.3 THE ONGOING QUEST TO REVEAL AND UNDERSTAND PARASITE DIVERSITY	53
14	DNA barcoding is one way to catalog parasite diversity	53
18	Some parasites exist in complexes of cryptic species	55
19	Whole lineages of unapparent parasites may escape our attention	57
	Metagenomics provides a new way to reveal parasite diversity	57
21	Studies of parasite diversity help provide a better foundation for taxonomy	58
23		
	2.4 OTHER WAYS TO CONSIDER PARASITE DIVERSITY	59
23	Diversity within parasite species is extensive and important	60
24	Do parasites give rise to free-living organisms?	62
26		
27	REVIEW QUESTIONS	64
	REFERENCES	64

CHAPTER 3 THE PARASITE'S WAY OF LIFE

3.1 A HISTORICAL PERSPECTIVE OF THE PARASITE LIFE CYCLE

Early medical and natural history studies gave rise to an understanding of parasite life cycles 67

Mosquito transmission was first demonstrated for filarial worms 69

Arthropod transmission for filarial worms suggested that other diseases may be similarly transmitted 71

3.2 AN OVERVIEW OF PARASITE LIFE CYCLES

Parasites with direct life cycles use only a single host 72

Two or more hosts are necessary for those parasites with indirect life cycles 73

3.3 THE PARASITE'S TO DO LIST

Effective transmission is essential for all parasites 77

High reproductive rates are common in many parasite life cycles 85

Both sexual and asexual reproduction are used by apicomplexans such as *Toxoplasma gondii* 88

Parasites may use strategies other than high fecundity to achieve transmission 90

Many factors can complicate an understanding of parasite transmission 90

Mathematical models provide a useful tool to predict transmission rates 92

Many parasites must migrate to specific sites or tissues within the host 93

The evolution of complex migration within a host is not always clear 96

Parasites are adapted to maintain their position on or within the host 97

Finding a mate is a requirement for many sexually reproducing parasites 98

Parasite genomes reflect their adaptations to a parasitic lifestyle 99

The relationship between parasitism and genome size is not always clear 99

Propagules are released through a portal of exit 101

Parasites undergo complex developmental changes in response to environmental cues 101

Epigenetic phenomena and co-opting of host signaling molecules may be important in parasite development 105

REVIEW QUESTIONS

REFERENCES

CHAPTER 4 HOST DEFENSE AND PARASITE EVASION

4.1 AN EVOLUTIONARY PERSPECTIVE ON ANTI-PARASITIC IMMUNE RESPONSES

Prokaryotes have developed remarkable immune innovations during their billions of years encountering parasites 112

Many kinds of parasites compromise the health of plants so it is important to know how plants defend themselves 113

Although plants lack specialized immune cells, they still can mount effective, long-term responses to parasites 115

Many nematode species are specialized to parasitize plants 116

Invertebrates have distinctive and diverse innate immune systems 117

Invertebrates, including vectors and intermediate hosts, mount immune responses to contend with their parasites 118

Invertebrates also adopt distinctive behaviors to supplement their anti-parasite immune responses 120

Parasites suppress, manipulate, and destroy invertebrate defense responses 122

Some parasites rely on symbiotic partners to subvert the immune responses of their invertebrate hosts 123

Some invertebrates enlist symbionts to aid in their defense 124

Researchers hope to manipulate invertebrate immune systems to achieve parasite control 125

4.2 AN OVERVIEW OF VERTEBRATE DEFENSE

4.3 IMMUNE RESPONSES TO EUKARYOTIC PARASITES

Recognition of PAMPS initiates the immune response to protozoa 129

Immune responses to protozoa include both humoral and cell mediated components 131

Protective immunity to malaria develops as a consequence of repeated exposure 133

Immune responses are generated against each stage in the *Plasmodium* life cycle 134

Helminth parasites provoke a strong Th-2 response 137

Extensive changes to the intestinal epithelium occur in response to intestinal helminths 140

Immunocompromised hosts are more vulnerable to parasitic infection and increased pathology 141

4.4 PARASITE EVASION OF HOST DEFENSES	143	<i>Toxoplasma gondii</i> may both contribute to and help to prevent atherosclerosis	180
Many parasites are able to evade complement-mediated innate immune responses	143	5.2 PARASITES AND HOST BEHAVIOR	180
Intracellular parasites have evolved mechanisms to avoid destruction by host cells	144	Some parasites may modify host behavior to facilitate transmission	180
Parasites may interfere with intracellular signaling pathways	145	The mechanisms that parasites use to alter host behavior are obscure	182
Some parasites interfere with antigen presentation, resulting in an impaired immune response	146	Infected hosts may display unusual neurotransmitter profiles in their central nervous systems	183
Some parasites regularly change their surface antigens to avoid immune responses	147	5.3 PARASITE-MEDIATED AMELIORATION OF PATHOLOGY	185
Parasites frequently suppress or alter host immune responses by interfering with cell communication	150	Parasitic infection may be required for proper immune system development	186
Some parasites render themselves invisible to immune detection	151	Certain intestinal helminths may reduce the host inflammatory response	187
Various parasites are able to undermine the effector functions of antibodies	152	Intestinal helminth infection results in activation of regulatory T cells	188
REVIEW QUESTIONS	153	Intestinal helminths can be administered therapeutically	188
REFERENCES	154	REVIEW QUESTIONS	189
CHAPTER 5 PARASITE VERSUS HOST: PATHOLOGY AND DISEASE	159	REFERENCES	190
5.1 PATHOLOGY RESULTING FROM PARASITIC INFECTIONS	160	CHAPTER 6 THE ECOLOGY OF PARASITISM	193
Parasites can induce pathogenesis in various ways	160	6.1 DEFINING THE HABITATS OF PARASITES	193
Pathology can be categorized as one of several general types	161	Parasites occupy multiple habitats in succession	194
Parasites can cause direct trauma to host cells, tissues, and organs	162	Parasites have microhabitat preferences and occupy specific sites within their hosts	194
Mechanisms underlying the pathogenicity of <i>Entamoeba histolytica</i> remain obscure	165	Host specificity is one of parasitism's most distinctive properties	198
Parasitic infection can alter host-cell growth patterns	166	Encounter and compatibility filters determine the range of host species used by a parasite	199
Many parasites adversely affect host nutrition	170	The origins and consequences of host specificity are debated	200
<i>Plasmodium</i> infections can result in host iron deficiency	171	Underlying mechanisms dictating specificity are also often not known	201
Toxins are a less frequent component of parasite pathology	173	6.2 PARASITE POPULATION BIOLOGY	202
Pathology often results from immune-mediated damage to host cells and tissues	175	Parasite populations are complex	202
Immunopathology is an important component of the pathology observed in malaria	177	Parasites often show aggregated (overdispersed) distributions in their hosts	204
Granulomas formed in response to parasite antigen are both protective and pathological	178	Both density-independent and density-dependent factors influence parasite population size	206
Parasites may serve as a trigger for autoimmunity	179	Intraspecific competition can regulate parasite populations in different ways	208

Parasite population studies often require a long-term perspective and detailed sampling	210	Models for parasites with complex life cycles involving vectors become more complex	248
6.3 PARASITE COMMUNITIES	210	New models open the black box and estimate microparasite populations within hosts and the influences on them	249
The richness of parasite communities varies among host species for reasons that are still debated	212	Models need to take spatial and temporal factors into account	250
Most studies suggest parasite communities are stochastic in nature	213	Some individual hosts may serve as superspreaders	251
Parasite species within infracommunities engage in negative and positive interactions with one another	213	REVIEW QUESTIONS	253
Generalizable patterns are also elusive in component communities of parasites	217	REFERENCES	254
Human parasites have a distinctive community ecology	218	CHAPTER 7 EVOLUTIONARY BIOLOGY OF PARASITISM	259
6.4 THE ROLE OF PARASITES IN FOOD WEBS AND ECOSYSTEMS	219	7.1 MICROEVOLUTION IN PARASITES	260
Parasites can be a food source for other organisms	221	The subdivided nature of their populations influences the evolution of parasites	261
6.5 GLOBAL PATTERNS IN PARASITE DIVERSITY	224	The effective population size, N_e , influences parasite evolution	261
6.6 PARASITE EFFECTS ON HOST ECOLOGY	225	The mode of parasite reproduction affects microevolutionary change	262
Hosts try both to avoid infection and to actively remove parasites if they do become infected	225	Stability of the host environment influences parasite microevolution	265
Hosts also change their diets and engage in self-medication when infected	228	The mobility of parasites impacts their evolution, as exemplified by bird lice	265
Parasites influence host migratory behavior	229	Parasite microevolutionary change is strongly impacted by host mobility	267
Parasites can regulate host populations, but examples are few	230	A parasite's life cycle also affects the potential for evolutionary change	267
Parasites influence competitive interactions among hosts	233	7.2 COEVOLUTION OF PARASITE–HOST INTERACTIONS	269
Parasites can manipulate their hosts to affect the likelihood of predation	234	Parasites and hosts reciprocally affect each other's evolution	269
6.7 ECOLOGICAL IMMUNOLOGY	238	Parasites and hosts engage in arms races	271
6.8 THE METABOLIC THEORY OF ECOLOGY AND PARASITES	241	In parasite–host relationships, there can be an advantage to being rare	273
6.9 EPIDEMIOLOGY AND ITS RELATIONSHIPS WITH ECOLOGY	242	Parasites and hosts can be locally adapted, or maladapted, to one another	273
Modeling is an invaluable approach to the study of infectious diseases	243	Some factors conspire to limit strong coevolutionary dynamics between parasites and hosts	274
Microparasites exemplify basic modeling approaches that estimate population size and clarify transmission	244	7.3 THE EVOLUTION OF VIRULENCE	274
Models of macroparasite populations and transmission involve keeping track of individual parasites	246	Virulence and transmission biology of parasites are linked	275
		The trade-off hypothesis requires a nuanced approach	276
		The mode of transmission influences virulence	278

7.4 MACROEVOLUTIONARY PARASITOLOGY	279		
New parasite species are potentially formed in at least three different ways	279		
Different outcomes can be expected when parasites or their hosts diversify	284		
What does the evidence suggest about how parasites have speciated?	285		
Does sympatric speciation occur in parasites?	287		
Host switches can enable radiations in parasites	289		
Parasites go extinct, sometimes along with their hosts	290		
Macroevolutionary patterns among parasites are not yet very clear	293		
7.5 SOME DISTINCTIVE ASPECTS OF PARASITE EVOLUTION	296		
Organisms have repeatedly adopted parasitism by more than one route	296		
Some parasites are derived from their hosts	297		
Selection can favor the evolution of complex parasite life cycles	298		
Sometimes complex life cycles are simplified secondarily	299		
Parasites often have simplified bodies or genomes but also have other talents not seen in free-living organisms	300		
7.6 PARASITE EFFECTS ON HOST EVOLUTION	301		
Parasites select for genetic changes and genetic diversity in their hosts	301		
Parasites affect the evolution of host MHC genes	303		
Parasites play a role in host selection of mates	304		
Host speciation may be facilitated by parasites	307		
Can infection directly cause speciation?	309		
Parasites are believed to favor the evolution of sexual reproduction in their hosts	311		
Parasites can cause extinction of host species	312		
REVIEW QUESTIONS	313		
REFERENCES	314		
CHAPTER 8 PARASITES AND CONSERVATION BIOLOGY	317		
8.1 SOME THEORY ABOUT PARASITES AND CONSERVATION BIOLOGY	319		
Theory often predicts parasites will not extirpate their hosts, but by no means always	319		
Persistent parasite infectious stages may also favor demise of host populations	320		
		The presence of a parasite-tolerant host species may endanger a susceptible one	321
		8.2 PARASITES INFLUENCE EFFORTS TO PRESERVE HOSTS	322
		Parasites can cause extinction of host species	322
		Parasites work in concert with other stressors to affect hosts	323
		The impact of parasitism is influenced when hosts occur in small or fragmented populations.	324
		Parasites can strongly affect hosts with reduced genetic variation	326
		Captive host populations are often very vulnerable to parasites	328
		Parasites are frequently transferred from abundant host species to rare relatives, including from humans to our great ape cousins	328
		Farming can pose parasite problems for wild host species	329
		Parasites of an iconic symbol—the giant panda—point out our need to know more	330
		8.3 DANGERS RESULTING FROM SPECIES INTRODUCTIONS	331
		Parasites can be introduced with their hosts and have spillover effects	332
		Introduced hosts can favor indigenous parasites and cause spillback effects	333
		Sometimes introduced nonhost organisms can influence indigenous parasite transmission	335
		Invading hosts can benefit by leaving their natural enemies, such as parasites, behind	336
		Invasive hosts can potentially be controlled by parasites from their original range	337
		Introductions of parasites or hosts often fail	338
		Translocations of endangered host species can have unforeseen consequences	338
		Can invasional meltdown occur?	339
		8.4 PARASITES AS INDICATORS OF ENVIRONMENTAL HEALTH	339
		Parasites can help us monitor ecosystem integrity	339
		8.5 PARASITES AS INFERENTIAL TOOLS TO PRESERVE HOST BIODIVERSITY	342
		Parasites can provide information useful to preserving their hosts	342
		8.6 THE NEED TO PRESERVE PARASITE DIVERSITY	344
		Parasites play key roles in maintaining ecosystem health	344
		Parasites are drivers of biodiversity	345

Parasites are a source of pharmacological and therapeutic novelties	345	Drug resistance can be prevented or reversed	382
Slip sliding away—parasite diversity is being lost	346	Concerns about resistance highlight the need for new anti-parasitic drugs	385
REVIEW QUESTIONS	351	New drugs are also needed to replace older more toxic medications	387
REFERENCES	352	The manner in which new drugs are discovered has changed considerably	387
 		Potentially effective drugs usually require chemical modification prior to their use	388
CHAPTER 9 THE CHALLENGE OF PARASITE CONTROL	355	Economic issues often affect the rate at which new drugs are developed	389
9.1 STRATEGIES TO REDUCE PARASITE TRANSMISSION	356	9.3 VACCINES	390
Parasite transmission may be reduced in various ways	356	Vaccines must be safe and inexpensive, while inducing long-term immunity	392
Parasites using trophic transmission can be controlled by insuring food safety	357	Vaccines against eukaryotic parasites are particularly problematic	393
Proper sanitation is the key to controlling parasites transmitted via the fecal-oral route	358	Vaccines can be categorized into several types	394
Various other factors influence the success of control efforts	360	An effective malaria vaccine has been the object of intensive investigation	396
The control of vector-borne diseases focuses on reducing human–vector contact	362	Vaccines against different life-cycle stages offer different potential benefits	396
The discovery of DDT radically altered vector control efforts	362	Recent candidate vaccines may be used clinically in the near future	398
Newer insecticides provide alternatives to DDT	363	A few anti-eukaryote vaccines are available for veterinary use	398
Transmission of vector-borne parasites can be reduced through environmental manipulation	364	Vaccines against helminth parasites are being investigated	399
Biological control offers the possibility of low-cost, sustainable control	365	REVIEW QUESTIONS	401
The production of transgenic vectors provides hope as a means to reduce vector capacity	369	REFERENCES	402
9.2 ANTI-PARASITIC DRUGS	372	CHAPTER 10 THE FUTURE OF PARASITOLOGY	405
Various factors influence the selection of the best anti-parasitic drug in different situations	373	10.1 OUR FUTURE WORLD	405
Different drugs may be appropriate for treatment and for prophylaxis	374	10.2 SOME FUTURE CHALLENGES FOR PARASITOLOGISTS	407
Drugs may be used to either treat or protect individuals or to protect a population	374	There is always something new to be found under the parasitological sun	407
Certain drugs are active only against specific parasite life-cycle stages	375	We need to better understand the ecological and evolutionary roles of parasites	408
Drug use may affect the immune status of the population	377	Revealing how parasite and host molecules interact is needed to clarify many fundamental aspects of parasitism	411
The use of anti-parasitic drugs can lead to resistance	378	Climate change will affect parasites, but we know little about how	412
Genetic alterations can cause resistance in diverse ways	379		
Resistance poses a considerable problem for disease control programs	381		

10.3 CONTROLLING PARASITES IN THE FUTURE	417
Improved understanding of immunity should enable development of new anti-parasite vaccines, but so far the parasites are winning	417
Chemotherapy-based control is an arms race between human ingenuity and parasite evolvability	418
Integrated control may provide the best prospects for sustainable parasite control and is built on a thorough knowledge of parasite biology	420
Major programs are underway to eliminate many parasites as public health problems	422
We will need improved methods to detect low levels of parasite infection and transmission in the future	424
Provision of improved living conditions, including education, will further discourage parasite transmission	425
REVIEW QUESTIONS	426
REFERENCES	427
ROGUES' GALLERY OF PARASITES	429
THE PROTOZOA	430
PHYLUM PLATYHELMINTHES	458
PHYLUM NEMATODA	479
THE ARTHROPODS	496
OTHERS	518
GLOSSARY	527
INDEX	539