Carlos Brisola Marcondes
Editor

Arthropod Borne Diseases

Springer

Arthropod Borne Diseases

Carlos Brisola Marcondes
Editor

Arthropod Borne Diseases

Springer

Editor
Carlos Brisola Marcondes
Department of Microbiology
Immunology and Parasitology
Center of Biological Sciences
Federal University of Santa Catarina
Florianópolis, SC, Brazil

ISBN 978-3-319-13883-1 ISBN 978-3-319-13884-8 (eBook)
DOI 10.1007/978-3-319-13884-8

Library of Congress Control Number: 2016954203

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This book is dedicated to
Maria Helena, Mariana, and Melina, for a life of happiness
Insects, for a life of work

Foreword

The purpose of this book is to provide easily accessible and readily understandable information related to arthropod-borne diseases. It contains 38 chapters written by more than 50 experts from several countries and provides information on vector and pathogen biology, diagnosis, treatment and prevention as well as ecology and epidemiology, topics essential to detect their occurrence and initiate timely intervention. The repeated evolution of blood feeding by wide variety of arthropods has resulted in their conflicting relationship with animals, including humans, by allowing them to serve as vectors of many pathogens, cause allergic reactions or provide a nuisance through their bites. Diseases caused by pathogens transmitted by arthropods such as malaria and dengue fever have strongly influenced human history and continue to be important in tropical and temperate countries. Climate change and the increased mobility of humans and domestic animals have resulted in the emergence of disease in unexpected situations, such as chikungunya and zika viruses in the New World, visceral leishmaniasis in Finland and sleeping sickness in the USA.

The overarching objective of this book is to prevent suffering and save lives by providing information accessible to health professionals and laypersons as well as students, scientists and researchers. Even though directed to solve problems, an effort was made to “guard against stripping the science in lieu of its poetry,” to enhance the interest and stimulate research.

Preface

Arthropod parasites have always had a "conflicting" relationship with animals including humans. Due to their need to feed on blood or other host tissues, they serve as vectors of pathogenic viruses, bacteria, protozoa, and helminths, cause severe allergic reactions, or simply provide nuisance due to their bites.

Some of the most important diseases affecting human history, such as malaria, nagana, yellow fever, and plague, are arthropod borne and remain public health problems today. Others such as Chikungunya and Zika viruses recently have emerged as problems of global proportions. The growing knowledge of pathogenic mechanisms, diagnosis, treatment, and prophylaxis has not been well divulged, and therefore many public health providers remain scarcely informed and believe these diseases do not occur in their day-to-day practice. As a consequence, many preventable deaths have occurred in both endemic and non-endemic countries and regions. As an example, in Brazil, the probability of death by malaria in an infected patient is 1000 times greater in non-endemic areas than in the endemic Amazonian region. Recent reports of deaths by malaria caused by *Plasmodium falciparum* in Rio de Janeiro and of delay in the correct diagnosis of malaria caused by *P. vivax* in Florianopolis emphasize the need for adequate health provider awareness. The more exotic findings of a fatal congenital case of Chagas disease, recently diagnosed in Spain, and 244 cases of African trypanosomiasis in Europe and the USA from 1902 to 2012 (see Chap. 18) emphasize the need of a good anamnesis, always including the travel history of the patient, and of a comprehensive knowledge of arthropod-borne diseases. It should be remembered that "the death of one man is a tragedy; the death of millions is a statistic."[1]

Infectious patients, agents, and vectors are mobile and may be undiagnosed in new areas; therefore it is dangerous to affirm that "this does not occur here." For example, several dogs and sand flies have recently been found infected by *Leishmania infantum* in the Santa Catarina Island in Santa Catarina, one of the few Brazilian states where no visceral leishmaniasis previously had been reported. The apparent nonoccurrence of diseases may sometimes reflect "the happiness that results from ignorance."

Because human beings and other animals frequently share arthropod parasites and the pathogens they transmit, it would not be sensible to analyze separately parasites of medical and veterinary importance. The finding of

[1] Attributed to Josef Stalin

West Nile virus in alligators in Florida and of rickettsiae in ticks from snakes in Thailand emphasizes the complexity of studies on arthropod-borne disease. The old Jacob's (1957) expression "sea of *Toxoplasma* around us" should also be applied to these diseases.

Arthropod-borne diseases have been associated by lay persons and even by health professionals with tropical climates and forests, but they are widely distributed in the world; at least 17 arboviruses have been found in Canada, and malaria was previously a health problem in the UK and Finland.

Predominance of occurrence of several arthropod-borne diseases in poor people living in underdeveloped countries has made them neglected diseases, but for humanitarian and practical reasons, they should not be considered "someone else's problem." In 2012, 2200 cases of dengue were reported in Madeira Island, and some autochthonous cases occurred in France and Croatia. Dengue and Chikungunya fever (also transmitted by *Aedes aegypti*) have occurred in other countries of continental Europe, and international travels of humans and pets have introduced several pathogens into unexpected places, as shown, for example, by the recent finding of autochthonous visceral leishmaniasis in dogs in Finland.

Environmental changes as a consequence of human activities (e.g., deforestation and pollution) may influence the transmission and the distribution of diseases. Previous exposure to pathogens and nutritional status can influence the risks for disease. Knowledge of the clinical presentation resulting from arthropod-borne pathogen infections and of the associated conditions is essential for adequate diagnosis, treatment, and prevention. This knowledge must include information on the epidemiology of these diseases, current and potential distribution, and observation of conditions of life and previous travels.

The objective of the present book is to furnish to health workers and the general public information useful to solve problems related to most arthropod-borne diseases in the world. The case of Lyme disease, in which two worried mothers of children from the American city of Old Lyme, Connecticut, which were affected by a mysterious disease, found similar cases in the public health records[2] and informed the health authorities of the occurrence of 12 cases in the small community, unleashed the discovery of the causative agent, the natural hosts, and the tick vectors and illustrates the value of a well-informed general public.

I expect this book will contribute to saving lives and to improving health in many regions, most of them already affected by other serious problems, such as famine and wars, and frequently related diseases. Most diseases transmitted or caused by arthropods are included in this book; however, dracunculiasis, a helminthiasis caused by *Dracunculus medinensis* and transmitted by ingestion of crustaceans, is briefly referred in Chaps. 3 and 24 but not described in detail because of its trend toward eradication. Venomous arthropods (spiders, scorpions, bees, etc.) were not included, due to the availability of other recently published books. This book is focused on

[2]Dr. M. P. Deane (pers commun 1986), watching a lecture on Lyme disease, praised the availability of good libraries and statistics in small US cities.

diseases and must be accompanied and supplemented by other works on medical and veterinary entomology, if identification of vectors and more details of their biology are needed.

Even being a book directed to solve health problems, an effort was made to "guard against stripping our science of its share of poetry," as suggested by Marc Bloch for history, trying to enhance interest and stimulate research.[3]

Florianópolis, SC, Brazil　　Carlos Brisola Marcondes

[3] See: http://buscatextual.cnpq.br/buscatextual/visualizacv.do?id=K4783901J2.

About the only genuine sporting proposition
that remains unimpaired… is the war against
these ferocious little fellow creatures, which lurk in the
dark corners and stalk us in the bodies of rats, mice, and
all kinds of domestic animals; which fly and crawl with the
insects, and waylay us in our food and drink and even in our love

Hans Zinsser (1935)

Acknowledgments

To Springer, for acceptance of the publication of this work, and to all authors, for believing in the usefulness of such work and for collaborating in this arduous task.

To Ronald Sherman, for the review and suggestions for maggot therapy section. To Amer Al-Jawabreh, Caryn Bern, Henk D. F. H. Schallig, Jane da Silva, José Diomedes Barbosa Neto, Kwan Poo Chang, Martin J. R. Hall, Naomi Dunning-Foreman, Paola Marchesini, Pedro Luiz Tauil, R. A. Sherman, Salman Singh, Shikha Arora, and Wes Watson, for sending publications, figures, and/or information useful for the book. To Alan Kahan (Entomological Society of America), Amy Ellis-Thompson (Maney Publishing), José Venzal, Luiz Henrique Guimarães (Federal University of Bahia), Natalino Yoshinari, Societé Française de Ophtalmologie, PLOS, US Centers for Disease Control and Prevention (CDC), US National Oceanic and Atmospheric Administration, and Wikimedia Commons for authorization to utilize photos or tables. To Leonardo Vincensi for the drawings of the examples of Chilopoda and Diplopoda.

To all authors, for their effort, with so many tasks, especially to Pedro Marcos Linardi, my professor and friend for 40 years, for delivering his chapter in so difficult familiar conditions.

Contents

Contributors

Leucio Camara Alves Department of Veterinary Medicine, Federal Rural University of Pernambuco, Recife, Brazil

Maria Paloma Silva de Barros Department of Microbiology, Aggeu Magalhães Center of Research (CPqAM/Fiocruz), Oswaldo Cruz Foundation, Recife, PE, Brazil

Carla de Lima Bicho Department of Biology, Center of Biological Sciences and Health, State University of Paraiba, Campina Grande, PB, Brazil

Emanuele Brianti Department of Veterinary Sciences, University of Messina, Messina, Italy

Eric P. Caragata René Rachou Center of Research, Belo Horizonte, MG, Brazil

Keith H. Carter Department of Communicable Disease and Health Analysis, Pan American Health Organization/World Health Organization, Washington, DC, USA

Cédric Chesnais Joint Research Unit 233 "TransVIHMI", Institut de Recherche pour le Développement, Montpellier University, Montpellier, France

Marta S. Contigiani Arbovirus Laboratory, Institute of Virology "Dr. J. M. Vanella", National University of Córdoba, Córdoba, Argentina

Iliano V. Coutinho-Abreu Vector Molecular Biology Section, Laboratory of Malaria and Vector Research, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Rockville, MD, USA

James Lee Crainey Leônidas e Maria Deane Institute (Fiocruz Amazônia), Manaus, Amazonas, Brazil

Filipe Dantas-Torres Department of Immunology, Aggeu Magalhães Research Center, Recife, PE, Brazil

Department of Veterinary Medicine, University of Bari, Valenzano, Italy

João Carlos Pinto Dias René Rachou Center of Research, Oswaldo Cruz Foundation, Belo Horizonte, MG, Brazil

Luis A. Diaz Arbovirus Laboratory, Institute of Virology "Dr. J. M. Vanella", National University of Córdoba, Córdoba, Argentina

Institute for Biological and Technical Researches, CONICET-UNC, Córdoba, Argentina

John Patrick Ehrenberg Western Pacific Regional Office of the World Health Organization, Merida, Yucatan, Mexico

Rainier P. Escalada Department of Communicable Disease and Health Analysis, Pan American Health Organization/World Health Organization, Washington, DC, USA

Alexsandra R.M. Favacho Laboratory of Hantaviroses and Rickettsioses, Oswaldo Cruz Institute, Oswaldo Cruz Foundation, Rio de Janeiro, RJ, Brazil

Gilberto Fontes Federal University of São João del Rei, Campus Centro Oeste, Divinópolis, Minas Gerais, Brazil

Annunziata Giangaspero Department of Science of Agriculture, Food and Environment, University of Foggia, Foggia, Italy

Raquel M. Gleiser Centro de Relevamiento y Evaluación de Recursos Agrícolas y Naturales, Instituto Multidisciplinario de Biología Vegetal (IMBIV), Universidad Nacional de Córdoba (UNC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Córdoba, Argentina

Edmundo C. Grisard Department of Microbiology, Immunology and Parasitology, Center of Biological Sciences, Federal University of Santa Catarina, Florianópolis, SC, Brazil

Hilary Hurd Centre for Applied Entomology and Parasitology, School of Life Sciences, Keele University, Keele, Staffordshire, UK

Tereza Cristina Leal-Balbino Department of Microbiology, Aggeu Magalhães Center of Research (CPqAM/Fiocruz), Oswaldo Cruz Foundation, Recife, PE, Brazil

Hermenio C. Lima Division of Dermatology, Department of Medicine, Michael G. DeGroote School of Medicine, McMaster University, Hamilton, ON, Canada

Pedro Marcos Linardi Department of Parasitology, Institute of Biological Sciences, Federal University of Minas Gervais, Belo Horizonte, Minas Gerais, Brazil

Susan E. Little Department of Veterinary Pathobiology, Center for Veterinary Health Sciences, Oklahoma State University, Stillwater, OK, USA

Sérgio Luis Bessa Luz Leônidas e Maria Deane Institute (Fiocruz Amazônia), Manaus, Amazonas, Brazil

Cláudio Mafra Laboratory of Parasitology and Molecular Epidemiology, Department of Biochemistry and Molecular Biology, Federal University of Viçosa, Viçosa, MG, Brazil

Carlos Brisola Marcondes Department of Microbiology, Immunology and Parasitology, Center of Biological Sciences, Federal University of Santa Catarina, Florianópolis, SC, Brazil

Maria Angélica Monteiro de Mello Mares-Guia Laboratory of Hantaviroses and Rickettsioses, Oswaldo Cruz Foundation, Oswaldo Cruz Institute, Rio de Janeiro, RJ, Brazil

Jansen Fernandes Medeiros Fundação Oswaldo Cruz - Fiocruz Rondônia, Porto Velho, Rondônia, Brazil

Luiz C. Miletti Department of Animal and Foods Production, Center of Agroveterinary Sciences, State University of Santa Catarina, Lages, SC, Brazil

Hélio Amante Miot Department of Dermatology, UNESP Medical School, Botucatu, SP, Brazil

Carlos Emmanuel Montandon Laboratory of Parasitology and Molecular Epidemiology, Department of Biochemistry and Molecular Biology, Federal University of Viçosa, Viçosa, MG, Brazil

Luciano A. Moreira René Rachou Center of Research, Belo Horizonte, MG, Brazil

Gerson Azulim Müller Federal Institute of Education, Science and Technology Farroupilha, Panambi, RS, Brazil

Maria Ogrzewalska Laboratory of Hantaviroses and Rickettsioses, Oswaldo Cruz Institute, Oswaldo Cruz Foundation, Rio de Janeiro, RJ, Brazil

Maria Betânia Melo de Oliveira Department of Biochemistry, Federal University of Pernambuco, Recife, PE, Brazil

Domenico Otranto Department of Veterinary Medicine, University of Bari, Valenzano, Italy

Felipe Arley Costa Pessoa Leônidas e Maria Deane Institute (Fiocruz Amazônia), Manaus, Amazonas, Brazil

Kim Picozzi School of Biomedical Sciences, Centre for Infectious Diseases, College of Medicine and Veterinary Medicine, University of Edinburgh, Edinburgh, UK

Sébastien Pion Joint Research Unit 233 "TransVIHMI", Institut de Recherche pour le Développement, Montpellier University, Montpellier, France

William K. Reisen Department of Pathology, Microbiology and Immunology, School of Veterinary Medicine, Center for Vectorborne Diseases, University of California, Davis, CA, USA

Eliana Maria Mauricio da Rocha Federal University of São João del Rei, Campus Centro Oeste, Divinópolis, Minas Gerais, Brazil

Tatiana Rozental Laboratory of Hantaviroses and Rickettsioses, Oswaldo Cruz Institute, Oswaldo Cruz Foundation, Rio de Janeiro, RJ, Brazil

Vladimir da Mota Silveira-Filho Department of Biology, University of Pernambuco, Garanhuns, PE, Brazil

Prabhjot Singh Department of Communicable Disease and Health Analysis, Pan American Health Organization/World Health Organization, Washington, DC, USA

Marise Sobreira Department of Microbiology, Aggeu Magalhães Center of Research (CPqAM/Fiocruz), Oswaldo Cruz Foundation, Recife, PE, Brazil

Lorena I. Spinsanti Arbovirus Laboratory, Institute of Virology "Dr. J. M. Vanella", National University of Córdoba, Córdoba, Argentina

Mário Steindel Department of Microbiology, Immunology and Parasitology, Center of Biological Sciences, Federal University of Santa Catarina, Florianópolis, SC, Brazil

Dietmar Steverding Norwich Medical School, University of East Anglia, Norwich, UK

Patricia H. Stoco Department of Microbiology, Immunology and Parasitology, Center of Biological Sciences, Federal University of Santa Catarina, Florianópolis, SC, Brazil

Laura B. Tauro Laboratory of Arbovirus, Institute of Virology "Dr. J. M. Vanella", National University of Córdoba, Córdoba, Argentina

Patricia Jacqueline Thyssen Department of Animal Biology, Institute of Biology, State University of Campinas, UNICAMP, Campinas, SP, Brazil

Donato Traversa Faculty of Veterinary Medicine, Teaching Veterinary Hospital, University of Teramo, Teramo, Italy

Gerrit Uilenberg "A Surgente", Cargèse, France

Jesus Valenzuela Vector Molecular Biology Section, Laboratory of Malaria and Vector Research, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Rockville, MD, USA

Pedro F.C. Vasconcelos National Reference Laboratory of Arboviruses, Evandro Chagas Institute, Ananindeua, Brazil

National Institute of Science and Technology for Viral Hemorrhagic Fevers, Ananindeua, Brazil

PAHO/WHO Collaborating Center for Arbovirus Research and Diagnostic Reference, Evandro Chagas Institute, Ministry of Health, Ananindeua, Brazil

Department of Pathology, Pará State University, Belém, Pará, Brazil

Part I

Introduction

Generalities and Importance of Arthropod-Borne Diseases

1

Carlos Brisola Marcondes

Abstract

Arthropod-borne diseases are very important for human and animal health. A brief introduction is developed on the importance and needs for the control of such diseases.

Keywords

Arthropod-borne diseases • Malaria • Sleeping sickness • Nagana

Arthropods are a very large and important group of animals, present in every place in the planet. They seem to exist since at least the Cambrian "explosion" (ca. 550 million years ago), and fossil insects were present in the Devonian, at 350 million years ago. Comparing their antiquity and ubiquity to ours, it is too anthropocentric to refer to them as "intruders in our world." It is necessary to learn how to live with (or among) them to minimize conflicts and protect the health of humans and domesticated animals and not cause excessive damage to the environment.

Several insects, all ticks, and some mites developed the capacity of sucking blood, causing problems to hosts, not only by the direct effect of bites and theft of blood but also due to the transmission of virus, bacteria, protozoa, and helminths. By the adaptation to transmission through vectors, these living beings got access to the hosts, without direct exposition to desiccation, rain, direct sunlight, etc.

There are currently almost 15,000 species of bloodsucking insects (Lehane 2005), ca. 880 of ticks (Jongejan and Uilenberg 2004), and many mites adapted to bloodsucking, and several lice and mites can feed on the skin and annexes. Most bloodsucking insects belong to Diptera, and several of the most important diseases are transmitted[1] by arthropods. They have caused great mortality and misery to mankind, sometimes influencing economy and history, and their control is very important for public health. For example, the mortality of malaria in the world was estimated at 584,000 deaths (367,000–755,000) with 184 million of cases in 2013 and was the tenth cause of mortality in the world, in 2012. The estimated

C.B. Marcondes (✉)
Department of Microbiology, Immunology and Parasitology, Center of Biological Sciences, Federal University of Santa Catarina,
88040-900 Florianópolis, SC, Brazil
e-mail: cbrisolamarcondes@gmail.com

[1] Although arthropods actually transmit agents able to cause diseases and not diseases, transmission of diseases is utilized in this book for practicability.

C.B. Marcondes (ed.), *Arthropod Borne Diseases*, DOI 10.1007/978-3-319-13884-8_1

annual incidence of cutaneous leishmaniasis in the world is 690,900, while that of visceral form (VL) is 202,200, in 98 countries and three territories on five continents (Alvar et al. 2012). Mortalities from VL, probably underreported, varied from 1.5 to 7.2 %, but more careful surveys indicated case fatality rates, respectively, of 10 and 20 % in South Sudan and India.

Several arthropod-borne diseases are very important for domestic animals and trypanosomiasis, for example, prejudice cattle breeding in 10 million km^2 of arable land in Africa (Itty 1996); nagana and sleeping sickness, respectively, cause a damage >US$4.5 billion/year and 50,000 deaths/year (Kabayo 2002). Babesiosis, several arboviruses, mange, bloodsucking flies, and ticks strongly influence the production of food. Eighty percent of cattle in the world are exposed to tick bites, with an impact of US$7.3/head year (FAO 1984). Long contact of human and domestic animal populations with diseases related or not to arthropods and availability of animals capable of domestication have contributed for the advantage of Eurasian populations (Diamond 1999).

Arthropod-borne diseases are frequently associated with poorness and precariousness of living conditions, contributing to aggravate such conditions, and this has contributed to make them neglected diseases. However, for humanitarian reasons and because they can cause disease to all people, they deserve great attention. For example, the association of dengue to precarious neighborhood is controversial, at least in Rio de Janeiro and other Brazilian cities (Teixeira et al. 2003; Machado et al. 2009).

Epidemiology of diseases is much diversified, and its study must be developed before they occur, to prevent suffering and deaths, and all control measures must be based in solid knowledge. As an example, an outbreak of yellow fever in Botucatu, in the Brazilian state of São Paulo in 2009, with 28 cases and 11 deaths, induced the vaccination of one million people that caused five deaths; a careful calculation of proportion of people to be vaccinated (Ribeiro et al. 2015) and/or a more complete knowledge of the mosquito fauna in the area would probably have minimized the mortality.

The sudden occurrence of an outbreak of Chagas disease linked to ingestion of sugarcane juice, in 2005, in the non-endemic Brazilian state of Santa Catarina (Steindel et al. 2008) emphasized the need of thorough studies of sylvatic cycle of *Trypanosoma cruzi* in the area. However, local researchers, after developing preliminary studies on this cycle in the 1980s, were induced to work in other fields of research, due to the nonavailability of resources. The recent cases of dermal leishmaniasis cases in the Santa Catarina Island justified the usual comment of the author in classes, pointing to the forest and saying that there is probably some *Leishmania* there, which someday would infect a human being and be perceived.

Many problems caused by arthropods are related to inadequate management of natural environment, promoting proliferation of vectors and their contact with parasites and human populations. The dream of “a world without flies” just after the discovery of organochlorine insecticides was not fulfilled, and most arthropod-borne diseases, after a time of successful control, continued to be very frequent and widely distributed. Control of such diseases must be based on solid knowledge of their many aspects and on the ecology of vectors and reservoirs.

References

Alvar J, Vélez ID, Bern C et al (2012) Leishmaniasis worldwide and global estimates of its incidence. Plos One 7, e35671

Diamond J (1999) Guns, germs and steel: the fate of human societies. W. W. Norton and Co., New York/London, p 457

FAO (1984) Ticks and tick-borne disease control: a practical field manual, vol I, Tick control. Food and Agriculture Organization of the United Nations, Rome, p 299

Itty P (1996) Profitability, efficiency and comparative advantage of African cattle meat and milk production: the case of trypanotolerant village cattle production. Agric Econ 14:33–44

Jongejan F, Uilenberg G (2004) The global importance of ticks. Parasitology 129:S3–S14

Kabayo JP. 2002. Aiming to eliminate tsetse of Africa. Trends Parasitol 18:473–475
Lehane MJ (2005) The biology of blood-sucking in insects. Cambridge University Press, Cambridge
Machado JP, Oliveira RM, Souza-Santos R (2009) Spatial analysis of dengue occurrence and living conditions in Nova Iguaçu, Rio de Janeiro state, Brazil. Cad Saúde Pública 25:1025–1034
Ribeiro AF, Tengan C, Sato HK et al (2015) A public health risk assessment for yellow fever vaccination: a model exemplified by an outbreak in the state of São Paulo, Brazil. Mem Inst Oswaldo Cruz 1:1–5
Steindel M, Pacheco LK, Scholl D et al (2008) Characterization of *Trypanosoma cruzi* isolated from humans, vectors, and animal reservoirs following an outbreak of acute human Chagas disease in Santa Catarina state, Brazil. Diagn Microbiol Infect Dis 60:25–32
Teixeira MG, Barreto ML, Costa MCN et al (2003) Dynamics of dengue virus circulation in a metropolitan area of Brazil. Epid Serv Saúde 12:87–97

Epidemiology

2

William K. Reisen

Abstract

Concepts required to understand the epidemiology and ecology of vector-borne diseases are presented in sections that cover components of the transmission cycle, modes of transmission by the vector, different types of transmission cycles based on vertebrate hosts, vector incrimination, interseasonal maintenance mechanisms, and surveillance. Minimal components required for transmission of a vector-borne pathogen include a competent vertebrate host and an arthropod vector, a virulent pathogen, and a suitable environment. The efficiency of transmission depends on the frequency of contact between host and vector and is delineated by blood meal acquisition behavior by the vector and environmental conditions that drive the system. Transmission cycles mostly have evolved from sylvan zoonoses comprised of a diverse variety of hosts and vectors to urbanized anthroponoses comprised of human hosts and a limited number of vectors that frequently rest and blood feed in houses. Vector incrimination is dependent upon the diagnosis of frequent field infection, degree of competent host contact, and vector competence determined experimentally. Many vector-borne pathogens appear to have evolved in the tropics, but have become a serious public, veterinary, or wildlife health problem after invading temperate latitudes. Here, interseasonal maintenance becomes a key element for pathogen persistence, delineates endemicity, and delimits distribution in time and space. Because outbreaks of vector-borne disease occur intermittently even in endemic areas, surveillance programs are required to track cases and the pathogen within transmission cycles in time and space to inform public health policy and provide operational decision support to direct intervention.

W.K. Reisen (✉)
Department of Pathology, Microbiology and Immunology, School of Veterinary Medicine, Center for Vectorborne Diseases, University of California, Davis, CA 95616, USA
e-mail: wkreisen@ucdavis.edu

C.B. Marcondes (ed.), *Arthropod Borne Diseases*, DOI 10.1007/978-3-319-13884-8_2

Keywords
Epidemiology • Ecology • Transmission cycles • Landscape • Vector incrimination • Vectorial capacity • Surveillance

2.1 Introduction

Epidemiology (etymology: epi = upon, demos = people, logos = study) developed as a science through the investigation of outbreaks of infectious diseases. As a modern discipline, it deals primarily with the natural history and spread of diseases within human and animal populations. Vector-borne diseases comprise a subset of infectious diseases and are caused by parasites that are transmitted by arthropods. The transmission cycle minimally consists of a competent arthropod vector, a susceptible vertebrate host, and a virulent parasite interacting within a favorable environment (Fig. 2.1). Where these factors come together in time and space is known as the *nidus* (literally nest or center) of infection (Pavloskiy 1966). The spread of parasites by arthropods is complex, because in addition to the myriad of interactions between the vertebrate host and the parasite to cause disease, an arthropod is required to distribute the parasite among uninfected hosts. The ecology, behavior, and physiology of the arthropod as well as environmental factors such as temperature and rainfall impact the transmission processes by affecting the rate of parasite acquisition and maturation within the arthropod host and distribution of the parasite to new hosts. Failure of any one of the basic cycle components may result in local parasite extinction.

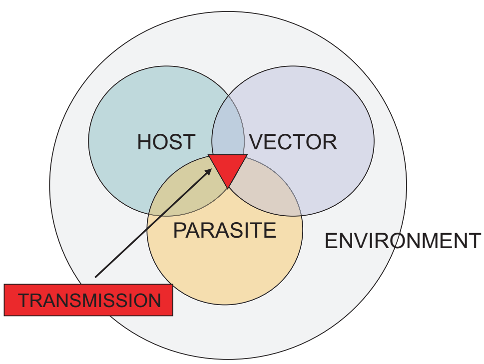

Fig. 2.1 Four required components of a vector-borne transmission cycle: (*1*) susceptible vertebrate host, (*2*) competent vector, (*3*) infectious parasite, and (*4*) suitable environment. Transmission occurs when all four components come together in time and space (Adapted from Reisen 2010)

With an epidemiological context, a *vector* is an arthropod responsible for distributing a parasite (not the disease) among vertebrate hosts. *Disease* is the response of the host to infection with the parasite. A *parasite* in this chapter is any organism, including viruses, bacteria, protozoa, helminths, and arthropods, which is dependent upon a host for its survival. Parasites may or may not cause disease. When a parasite injures its host and causes disease, it is referred to as a *pathogen*. A *vector-borne disease*, therefore, is an illness caused by a pathogen that is transmitted by an arthropod vector. *Facultative parasites* may have both free-living and parasitic forms, whereas *obligate parasites* are totally dependent upon their host(s) to provide their requisites for life. *Ectoparasites* live on or outside the host, whereas *endoparasites* live inside the host. When interacting with their hosts, ectoparasites produce an *infestation* that typically remains topical or peripheral, whereas endoparasites produce an *infection* when they invade host tissues or cells. The occurrence and severity of disease depend upon host–parasite interaction after infection and are often related to the immune response of the host. A host carrying a parasite is *infected*, whereas an infected host that is capable of transmitting a parasite is *infective* or *infectious*. A host capable of parasite maintenance without severe clinical symptoms is a *carrier*.

Understanding the epidemiology of arthropod-borne disease requires knowledge of the ecology, physiology, immunology, and genetics of parasite, arthropod vector, and vertebrate host populations and how they interact within their environment. Although specific methods of investigation vary considerably among the vast array of vectors and vector-borne parasites, overarching concepts unify the information necessary to understand the epidemiology of vector-borne diseases. Information on the disease typically evolves chronologically from the discovery of the parasite as the causative agent to identifying its mode of transmission by the arthropod vector(s) among vertebrate hosts and to monitoring, forecasting, and intervention. During the discovery period, clinical case definition and diagnosis are established enabling the tracking of human and/or veterinary cases in time and space, and the causative agent is identified, leading to the development of specific laboratory diagnosis and perhaps indicating that an arthropod may be responsible for transmission. The incrimination of the vector(s) requires a combination of field and laboratory investigation that measures abundance in time and space, blood-feeding patterns, field infection rates, and vector competence. Although short-term studies rapidly may determine the mode(s) of transmission, delineating the components of transmission cycles and interseasonal maintenance mechanisms typically requires years of careful ecological investigation and laboratory experimentation. Effective surveillance and control programs are best implemented after maintenance, amplification and epidemic transmission patterns have been described. Practically, discovery rarely progresses in the orderly fashion outlined above, and frequently, monitoring and management of cases progress more rapidly than the discovery of the vector or the mode(s) of transmission.

The current chapter details, in a general sense, the mechanisms by which arthropods serve as vectors of parasites that cause human or veterinary diseases. Although some examples are presented, details of specific parasites and their vectors will be described by others in subsequent chapters. This chapter revises and updates a similar presentation (Reisen 2009) that was published in Medical and Veterinary Entomology (Mullen and Durden 2009). Some overlap and redundancy between chapters were unavoidable as many of the definitions and concepts have not changed.

2.2 Components of Transmission Cycles

The components of a *transmission cycle* of an arthropod-borne disease include (1) a parasite that can multiply within both vertebrate and invertebrate host tissues, (2) a vertebrate host (or hosts) which develops a level of infection with the parasite that is infectious to the vector, (3) a competent arthropod vector that is able to acquire the parasite from the infected host and is capable of transmission, and (4) a suitable environment (Fig. 2.1).

2.2.1 The Parasite

A wide variety of human and animal parasites exploit arthropods as a means of transmission, including multiple families of viruses, bacteria, protozoa, and helminths. Vector-borne parasites have by necessity evolved mechanisms for tolerating high constant body temperatures and for evading the complex responsive immune systems of vertebrate hosts, as well as for tolerating variable body temperatures and avoiding the very different innate immune mechanisms of arthropod vectors. In addition, the parasites must locate and replicate in very different target organs and then develop mechanisms for transmission either by producing stages in vertebrates that aggregate where vectors blood feed or in vectors that can be deposited or injected during blood feeding. Asexual parasites such as viruses and bacteria employ the same life form to infect both vertebrate and arthropod hosts, whereas more highly evolved parasites such as protozoa and helminths have very different life stages within their vertebrate and arthropod hosts. In addition, some asexual parasites such as the plague bacillus at times may bypass the arthropod host and be transmitted directly from one vertebrate host to another by aerosol droplets or contact.

Among sexually reproducing parasites, the host in which gametocyte union occurs is the *definitive host*, whereas the host in which asexual reproduction occurs is the *intermediate host*. Vertebrates or arthropods can serve as either