Rev. sci. tech. Off. int. Epiz., 2009, **28** (2), 583-588

Vector-borne diseases

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Summary
Vector-borne diseases have been the scourge of man and animals since the beginning of time. Historically, these are the diseases that caused the great plagues such as the 'Black Death' in Europe in the 14th Century and the epidemics of yellow fever that plagued the development of the New World. Others, such as Nagana, contributed to the lack of development in Africa for many years. At the turn of the 20th Century, vector-borne diseases were among the most serious public and animal health problems in the world. For the most part, these diseases were controlled by the middle of the 20th Century through the application of knowledge about their natural history along with the judicious use of DDT (dichlorodiphenyltrichloroethane) and other residual insecticides to interrupt the transmission cycle between arthropod and vertebrate host. However, this success initiated a period of complacency in the 1960s and 1970s, which resulted in the redirection of resources away from prevention and control of vector-borne diseases. The 1970s was also a time in which there were major changes to public health policy. Global trends, combined with changes in animal husbandry, urbanisation, modern transportation and globalisation, have resulted in a global re-emergence of epidemic vector-borne diseases affecting both humans and animals over the past 30 years.

Keywords
Arbovirus – Arthropod – Arthropod vector – Parasite – Tick – Vector competence – Zoonosis.

History

Although early scholars recognised a relationship between certain insects and illness in humans and animals, the concept of disease transmission by arthropods is relatively new. It was in 1877 when Sir Patrick Manson first demonstrated that a parasite of humans, *Wuchereria bancrofti*, was transmitted among humans by a mosquito, *Culex pipiens fatigans* (*Cx. pipiens quinquefasciatus*). In 1893, Texas cattle fever was shown to be transmitted by the hard tick *Boophilus annulatus*, and in 1898, malaria was shown to be transmitted by anopheline mosquitoes. Since that time, many important disease pathogens of humans and animals have been shown to depend on blood-sucking arthropods to complete their transmission cycles.

Disease transmission

The pathogens transmitted by arthropods fall into four main taxa of microorganisms: nematodes or 'roundworms', protozoa, bacteria (including rickettsia and borrelia spp.) and viruses. Some are true parasites of humans (e.g. *W. bancrofti*), but most are zoonotic, with other animals serving as primary vertebrate hosts (reservoirs). Humans and domestic animals are incidental hosts for most vector-borne pathogens, and they may or may not contribute to the transmission cycle on a temporary basis; as a result, they are not usually required for survival of the pathogen in nature.

An arthropod may transmit disease agents from one person or animal to another in one or two basic ways, as outlined below.

Mechanical transmission

This consists of a simple transfer of the organism on contaminated mouthparts or other body parts. No multiplication or developmental change of the pathogen on or in the arthropod takes place during this type of transmission. Examples of pathogens that are transmitted in this way include various enteroviruses, bacteria, and protozoa that have a direct faecal-oral transmission cycle.

Insects, such as houseflies, may become contaminated with these pathogens while feeding on faeces and may transport them directly to the food of humans. Certain insects such as horseflies (family Tabanidae), which frequent numerous hosts over a short period of time, can mechanically transmit blood-borne and wound or open-sore pathogens as well.

Biological transmission

The most important type of transmission by arthropods is biological transmission. As the name implies, the pathogen must undergo some type of biological development in the body of the arthropod vector in order to complete its life cycle. There are four types of biological transmission.

Propagative transmission

Propagative transmission occurs when the organism ingested with the blood meal undergoes simple multiplication in the body of the arthropod. Arboviruses, for example, replicate extensively in various tissues of mosquitos, flies and ticks, and are transmitted to a new host in the salivary fluid of the arthropod when it takes a blood meal.

Cyclopropagative transmission

In this type of transmission, the pathogen undergoes a developmental cycle (changes from one stage to another) as well as multiplication in the body of the arthropod. The best example of a disease transmitted in this way is malaria, in which a single zygote may give rise to >200,000 sporozoites.

Cyclodevelopmental transmission

In cyclodevelopmental transmission the pathogen undergoes developmental changes from one stage to another, but does not multiply. With the filariae, for example, a single microfilaria ingested by a mosquito may result in only one third-stage infective larva. In most instances, however, the number of infective larvae is significantly lower than the number of microfilariae ingested with the blood meal.

Vertical and direct transmission

Some viruses and rickettsiae are transmitted from the female parent arthropod through the eggs to the offspring. If the pathogen actually infects the developing egg, this is termed 'transovarial transmission'. With some arboviruses, however, only the ovarial sheath and oviduct are infected, and the egg becomes infected as it passes down the oviduct and is inseminated. This type is distinguished from transovarial transmission and is called 'vertical transmission'. In either case, the newly hatched arthropod larval stages are infected with the pathogen, which is then transmitted to subsequent development stages of the arthropod ('trans-stadial transmission'). Veneral transmission of certain viruses has also been documented. Thus, male mosquitoes that become infected transovarially or vertically can transfer the virus to uninfected female mosquitoes in the seminal fluid during copulation. Finally, certain arboviruses have been shown to infect their tick or mosquito vectors when infected and uninfected arthropods co-feed in close proximity to each other on the same vertebrate host in the absence of viraemia in that host. The virus is apparently attracted to the uninfected female arthropod through a chemo-tactic response to the salivary fluid injected into the bite wound. These latter types of transmission have obvious epidemiological importance in the ultimate infection of humans or other animals and in the maintenance of the pathogen in nature.

Extrinsic incubation period

In all types of biological transmission, the pathogen needs time to develop inside the arthropod and to progress to the stage at which it becomes infective and can be transmitted. The period of time required for this to happen, called the *extrinsic incubation period*, is generally 7 to 14 days, depending on the pathogen, the vector, and various environmental factors, including temperature. With arboviruses, this means infection and replication in the salivary glands; with the malaria parasite, infectious sporozoites must invade the salivary glands; and with filariae, it means development of the juvenile worms to the infective 3rd stage larvae.

Factors influencing transmission

The ability of arthropods to transmit a disease agent is dependent on many complex factors. Successful mechanical transmission depends on the degree of contact insects have with the vertebrate hosts and on feeding behaviour. For example, the domestic housefly has been shown experimentally to be a mechanical vector for several intestinal pathogens, primarily because this insect breeds in large numbers, lives in intimate contact with humans, and has the bad habit of feeding on both faeces and food. Tabanid flies are mechanical vectors of viruses, bacteria and protozoa because they take frequent interrupted blood meals on animals. Certain flies can also transmit the bacteria that cause yaws and other tropical diseases from open sores.

The ability to transmit a pathogen biologically varies greatly among species of arthropods, and even among geographical strains within a species. Significant variation in susceptibility to become infected and subsequently to transmit a pathogen has been demonstrated in a number of arthropod vectors. Most work, however, has been done with mosquitoes, and variation in vector competence has been documented with all of the major disease agents they transmit (i.e. malaria and filarial parasites, and arboviruses). Thus, within a single mosquito species, it is common to find geographical strains that are good vectors and other strains that are poor vectors. Because the effectiveness of vectors (i.e. how susceptible they are to infection and how well they enable the pathogen to grow) is genetically controlled, vector competence may be expected to change as a result of selective pressure over time.

In addition to innate susceptibility to infection, the overall vectoral capacity of a vector species is influenced by other biological and behavioural characteristics of the arthropod population. The degree of contact the species has with humans or animals is influenced by the host preference, the intrinsic blood-feeding and resting behaviour of the vector, and the population density of the vector, human and animal hosts. Longevity, resting behaviour, flight behaviour, and oviposition (breeding) behaviour of the vector population are important intrinsic factors that are influenced by extrinsic environmental factors, such as temperature, humidity, wind, and rainfall.

Other extrinsic factors may influence whether an individual arthropod becomes infected with a pathogen. For example, it has been shown that mosquitoes ingesting animal blood containing both microfilariae and certain arboviruses have a higher viral infection rate because virus dissemination is facilitated by microfilariae escaping from the midgut into the hemocoel. Other factors may also influence this 'leaky gut' phenomenon and thus susceptibility to infection. Finally, infection of the arthropod vector can be influenced by the strain of parasite. This is especially important with the arboviruses.

Because arthropods are cold-blooded, transmission of disease in temperate regions is seasonal and usually only occurs during the warmer months; cessation of transmission can be correlated with temperature and day length, the principal factors that determine diapause and hibernation in the vector population. In the tropics and subtropics, transmission generally occurs year around, but increased seasonal transmission is most frequently correlated with the rainy season.

Systematics

Table I presents the orders and lower taxa of the phylum Arthropoda that are known to transmit disease pathogens of humans and animals. The order Diptera is by far the most important in terms of disease transmission, primarily because of the family Culicidae (mosquitoes).

Table I
Taxonomic groups of the phylum Arthropoda that transmit animal and human diseases

	Class Insecta	
Order	**Family**	**Important genera**
Siphonaptera	Pulicidae	*Pulex*
		Xenopsylla
		Ctenocephalides
	Ceratophyllidae	*Nosopsyllus*
		Diamanus
	Leptopsyllidae	*Leptopsylla*
Anoplura	Pediculidae	*Pediculus*
Hemiptera	Cimicidae	*Cimex*
	Reduviidae	*Triatoma*
		Rhodnius
		Panstrongylus
Diptera	Ceratopogonidae	*Culicoides*
	Psychodidae	*Phlebotomus*
		Lutzomyia
		Sergentomyia
	Simuliidae	*Simulium*
		Prosimulium
		Austrosimulium
	Culicidae	*Aedes*
		Anopheles
		Culex
		Mansonia
		Haemagogus
		Psorophora
		Sabethes
	Tabanidae	*Tabanus*
		Chrysops
	Glossinidae	*Glossina*
	Muscidae	*Musca*
		Fannia
		Muscina
	Chloropidae	*Hippelates*
		Siphunculina
	Calliphoridae	*Calliphora*
		Lucilia
		Phaenicia
		Phormia
		Chrysomya
		Cochliomyia
	Sarcophagidae	*Sarcophaga*
Dictyoptera	Blattidae	*Blatta*
		Periplaneta
		Blattella
	Class Arachnida	
Order	**Family**	**Important genera**
Parasitiformes	Ixodidae	*Ixodes*
		Amblyomma
		Haemaphysalis
		Hyalomma
		Dermacentor
		Rhipicephalus
		Boophilus
	Argasidae	*Argas*
		Ornithodoros
		Otobius
Suborder Mesostigmata	Dermanyssidae	*Liponyssus*
		Dermanyssus
		Ornithonyssus
		Pneumonyssus
Acariformes	Trombiculidae	
Suborder Prostigmata		*Leptotrombidium*

Table II
Vector-borne infections of man and animals

Pathogens	Disease	Animal reservoirs	Geographical distribution	Vector
Viruses				
Togaviridae				
	Chikungunya	Primates, humans	Africa, Asia	Mosquitoes
	Ross River fever	Marsupials, humans	Australia, South Pacific	Mosquitoes
	Mayaro	Birds	South America	Mosquitoes
	Onyong-nyong fever	Not known	Africa	Mosquitoes
	Sindbis fever	Birds	Asia, Africa, Australia, Europe, Americas	Mosquitoes
	Eastern equine encephalomyelitis	Birds	Americas	Mosquitoes
	Western equine encephalomyelitis	Birds, rabbits	Americas	Mosquitoes
	Venezuelan equine encephalomyelitis	Rodents	Americas	Mosquitoes
	Barmah Forest	Not known	Americas	Mosquitoes
Flaviviridae				
	Dengue fever (serotypes 1-4)	Primates, humans	Worldwide in tropics	Mosquitoes
	Yellow fever	Primates, humans	Africa, South America	Mosquitoes
	Kyasanur Forest disease	Primates, rodents, camels	India, Saudi Arabia	Ticks
	Omsk haemorrhagic fever	Rodents	Asia	Ticks
	Japanese encephalitis	Birds	Asia	Mosquitoes
	Murray Valley encephalitis	Birds	Australia	Mosquitoes
	Rocio	Birds	South America	Mosquitoes
	St. Louis encephalitis	Birds	Americas	Mosquitoes
	West Nile encephalitis	Birds	Asia, Africa, North America, Europe	Mosquitoes
	Tick-borne encephalitis	Rodents	Europe, Asia	Ticks
Bunyaviridae				
	Sandfly fever	Not known	Europe, Africa, Asia	Sandflies
	Rift Valley fever	Not known	Africa	Mosquitoes
	La Crosse encephalitis	Rodents	North America	Mosquitoes
	California encephalitis	Rodents	North America, Europe, Asia	Mosquitoes
	Crimean-Congo haemorrhagic fever	Rodents, sheep	Europe, Asia, Africa	Ticks
	Oropouche fever	Not known	Central and South America	Midges, mosquitoes
Rhabdoviridae				
Vesicular stomatitis virus	Vesicular stomatitis	Cattle, horses, pigs	Global	Phlebotomus flies, mosquitoes
Orbiviridae				
Bluetongue virus	Bluetongue	Cattle, sheep, goats	Global	Culicoides flies
Bacteria				
Yersinia pestis	Plague	Rodents	Global	Fleas
Francisella tularensis	Tularaemia	Rabbits, rodents	North America, Europe, Asia	Ticks, tabanid flies
Rickettsia	Q fever	Ungulates	Global	Ticks
Rickettsia rickettsii	Rocky Mountain spotted fever	Rabbits, rodents, dogs	Western hemisphere	Ticks
Rickettsia typhi	Murine typhus	Rats	Global	Ticks
Rickettsia conori	Boutonneuse fever	Dogs, rodents	Europe, Africa	Ticks
Rickettsia australis	Queensland tick typhus	Rodents	Australia	Ticks
Rickettsia siberica	Siberian tick typhus	Rodents	Asia	Ticks
Orientia tsutsugamushi	Scrub typhus	Rodents	Asia, Australia	Mites
Borrelia species	Relapsing fever	Rodents	Global	Ticks and lice
Borrelia burgdorferi	Lyme disease	Rodents	North America, Europe	Ticks

Table II (cont.)

Vector-borne infections of man and animals

Pathogens	Disease	Animal reservoirs	Geographical distribution	Vector
Protozoa				
Plasmodium spp.	Malaria	Primates, humans	Global	Anopheline mosquitoes
Trypanosoma rhodesiense	African trypanosomiasis	Ungulates	Africa	Glossina flies
Trypanosoma gambiense		Pigs, ungulates	Africa	Glossina flies
Trypanosoma brucei	Nagana	Ungulates	Africa	Glossina flies
Trypanosoma cruzi	Chagas disease	Dogs, cats, opossum	Western hemisphere	Triatomid bugs
Leishmania spp.	Leishmaniasis	Dogs, rodents	Asia, Africa, Europe, Central and South America	Phlebotomus flies
Babesia spp.	Piroplasmosis	Ungulates	Global	Ticks
Filaria				
Wuchereria bancrofti	Bancroftian filariasis	Humans	Global	Mosquitoes
Brugia malayi	Brugian filariasis	Humans, primates	Asia	Mosquitoes

Importance

Collectively, arthropods are responsible for hundreds of millions of cases of disease in man and animals each year (Table II). Over the past 30 years, there has been a global re-emergence of infectious disease in man and animals in general and vector-borne diseases in particular, with an increased frequency of epidemic transmission and expanding geographical distribution. A major problem is that the most important vector-borne diseases occur in the tropics, usually in the areas where resources are most limited and surveillance is poor. However, the shrinking world, with highly increased human and animal mobility due to air travel and commerce (globalisation) has made these diseases not just problems of the tropics; they present the world community with possibly its greatest health problem and threat to economic security today. This underscores the need for physicians and veterinarians in non-endemic areas to be aware of vector-borne diseases and to be knowledgeable about where they occur and how to recognise and treat them.

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Les maladies à transmission vectorielle

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Résumé

Les maladies à transmission vectorielle constituent depuis toujours un véritable fléau pour les populations humaines et animales. Ces maladies sont responsables des plus grandes épidémies de l'histoire, par exemple la peste noire en Europe au XIVe siècle et l'épidémie de fièvre jaune qui a accompagné la colonisation du Nouveau Monde. D'autres maladies, comme la trypanosomiase africaine (ou nagana), ont freiné le développement de l'Afrique pendant de nombreuses années. Au début du XXe siècle, les maladies à transmission vectorielle comptaient parmi les plus graves problèmes affectant la santé publique et la santé animale dans le monde. Dans la plupart des cas, ces maladies ont été maîtrisées au milieu du siècle grâce au progrès des connaissances sur leur histoire naturelle et à l'utilisation raisonnée du

DDT (dichlorodiphényltrichloroéthane) et d'autres insecticides résiduels afin de stopper le cycle de transmission entre le vecteur arthropode et l'hôte vertébré. Toutefois, ce succès a été suivi d'une période de relâchement entre les années 1960 et 1970, qui s'est traduite par une affectation des ressources vers d'autres objectifs que la prévention et la lutte contre les maladies à transmission vectorielle. Les années 1970 ont également connu de profondes transformations des politiques de santé publique. Ces changements mondiaux, auxquels s'ajoutent les transformations des systèmes d'élevage, l'urbanisation, les transports modernes et la mondialisation ont ouvert la voie à une réémergence, depuis une trentaine d'années, des épidémies à transmission vectorielle qui affectent les populations animales et humaines.

Mots clés
Arbovirus – Compétence vectorielle – Moustique – Parasite – Tique – Vecteur arthropode – Zoonose.

Enfermedades transmitidas por vectores

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Resumen
Las enfermedades transmitidas por vectores han sido un flagelo para el hombre y los animales desde la aurora de los tiempos. Estas son las enfermedades que históricamente han provocado grandes pestes, como la de 'muerte negra' que asoló Europa en el siglo XIV o la epidemia de fiebre amarilla que tanto lastró el desarrollo del Nuevo Mundo. Otras enfermedades, como la nagana, han contribuido a la postración de África durante muchos años. A principios del siglo XX, las enfermedades transmitidas por vectores figuraban entre los problemas de salud pública y animal más graves del mundo. La mayoría de ellas quedaron sojuzgadas a mediados de siglo gracias al conocimiento de su historia natural combinado con un uso juicioso del DDT (diclorodifeniltricloroetano) y otros insecticidas residuales para interrumpir el ciclo de transmisión entre el artrópodo y el anfitrión vertebrado. Tal éxito, sin embargo, inauguró un periodo de complacencia que duró hasta los años sesenta y setenta e indujo a detraer recursos de las labores de prevención y control de las enfermedades transmitidas por vectores. Los años setenta fueron también una época de profundos cambios en las políticas de salud pública. En los últimos 30 años, las dinámicas planetarias, conjugadas con la creciente mundialización y el nuevo panorama en cuanto a métodos de producción animal, urbanización y transportes, han provocado el resurgimiento en todo el mundo de enfermedades epidémicas transmitidas por vectores que afectan tanto a personas como a animales.

Palabras clave
Arbovirus – Competencia vectorial – Garrapata – Mosquito – Parásito – Vector artrópodo – Zoonosis.