

A review of bats as carriers of organisms which are capable of infecting man or domestic animals

By

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With 1 table

Resumen

Se hace una revisión de todos los microorganismos o parásitos reportados de los murciélagos, los cuales pueden infectar al hombre o a los animales domésticos.

Los resultados obtenidos por los autores a partir del examen de cerca de 20.000 murciélagos colombianos son incluidos. Las referencias que muestran infecciones experimentales de murciélagos con organismos patógenos para el hombre o los animales domésticos también son mencionadas.

Todos los Arbovirus, *Salmonella*, *Spirochaeta*, y *Leptospira* evidenciados en los murciélagos se incluyen en la lista, debido a que ellos son considerados patógenos potenciales, o por que los anticuerpos contra estos microorganismos, pueden ocurrir en el hombre o los animales domésticos.

Summary

A revision of the literature was made concerning the microorganisms and parasites recovered from bats which may infect man or domestic animals. The microorganisms and parasites recovered from 20,600 colombian bats, examined by the authors, are included.

References regarding experimental infections of bats which organisms pathogenic for man or domestic animals are also reported. The Arbo viruses *Salmonella* spp., *Spirochaeta* spp., *Leptospira* spp. reported from bats have been listed, because they are considered to be potential pathogens, or because antibodies against these microorganisms can be expected to occur in man or in domestic animals.

Zusammenfassung

In einer Übersicht werden alle bei Fledermäusen auftretenden Mikroorganismen und Parasiten zusammengestellt, die bekannterweise Menschen, Haustiere oder Nutzvieh infizieren können.

Die von den Verf. auf Grund von ca. 20 000 untersuchten Fledermäusen erhaltenen Ergebnisse werden angegeben. Ebenfalls wird hingewiesen auf künstliche Infektionen von Fledermäusen mit Organismen, die pathogen für den Menschen oder Haustiere sein können.

Alle Arten von Arbovirus, *Salmonella*, *Spirochaeta* und *Leptospira*, die aus Fledermäusen isoliert wurden, sind in die Liste aufgenommen, da sie entweder als potenzielle Krankheitserreger angesehen werden oder weil die Antikörper gegen diese Mikroorganismen im Menschen, in Haustieren oder Nutzvieh auftreten können.

Introduction

Bats have been a topic of discussion and speculation for centuries. Are the old tales true? Are bats really bearers of bad luck and disease? Because bats are the most numerous of all tropical mammals, and because their habits are so diverse, especially in regard to the food they eat, a study of bats is of importance.

FERNANDEZ DE OVIEDO wrote in 1514 "Many christians died until they learned from the indians how to cauterize the wounds inflicted by the vampire bats"; and in 1527 MOLINA SOLIS in his reports on the conquest of Yucatán described how thousands of bats attacked the men. In 1911 CARINI proved that the "Peste de Cadeiras" of cattle in the south of Brazil was due to rabies transmitted by bats. Since then hundreds of articles regarding the transmission of rabies by bats have been published. Extensive information on bat rabies has been published by CONSTANTINE (1967).

Recently it was reported that the rabies virus can be transmitted by air from bats to man (CONSTANTINE 1967) and that bats harbor Arbo viruses, fungi, bacteria and protozoa which are capable of infecting man and domestic animals. Bats are also used as laboratory animals in the study of Arbo viruses. The authors found in their study of colombian bats that these mammals carry many pathogens like parasites and fungi, and that the role of bats in the transmission of these organisms should not be underestimated. CONSTANTINE (1970) emphasized that the mobility of migratory bats is remarkable, and that they may transport pathogens between various continents.

The purpose of this publication is to review the literature pertaining to the microorganisms and parasites reported from bats which might infect man and/or domestic animals. Because the number of publications on the subject is too large, literature references have been limited to the first publications, to the latest review articles and to those articles giving major details. Naturally, the selection was the author's opinion, and it is not intended to underestimate the work of articles not mentioned, however, due to the volume literature (over 850 literature references) encountered on the subject, certain restrictions were necessary.

Methods

A complete literature review was made to find publications pertaining to microorganisms and parasites found in bats which may infect man or domestic animals. Also included are the results obtained by the authors from the examination of 20,600 colombina bats for the presence of microorganisms and parasites.

Arbo and L.C.M.-like viruses recovered from bats are included in this study even though some have not been proved to cause disease, antibodies against these viruses can be expected to occur in man and/or domestic animals. Isolates from bats of *Leptospira* spp., *Salmonella* spp. and *Spirochaeta* (*Borrelia* spp.) are reported because they are either considered to be pathogens or potential pathogens. The finding of antibodies against an organism almost always signifies past or present infection, and therefore, these results are included in the table. Results regarding experimental infection of bats or of bat tissue cultures are also included because it is possible that bats would be susceptible to these infections under suitable natural conditions.

The numerous bat parasites which are considered not capable of infecting man or domestic animals, the parasites of laboratory and wild mammals reported from bats, doubtful pathogens like *Bartonella rochalima*, *Grahamella* sp., etc. and the many ectoparasites of bats, are not included due to the fact that they are apparently not potential pathogens.

Domestic animals includes the following: bovines (*Bos* spp., and *Bubalus* spp.), camelines, cat, dog, equines (except zebras), goat, pig, reindeer, sheep, and domesticated duck, fowl, goose, and turkey.

The numerous microorganisms isolated in past times from bat guano and caves inhabited by bats are not included. Questionable diseases transmitted from bat to man like "ethiopian bat sickness" of RIZOTTI (112) were omitted.

Results

About 140 different taxa of microorganisms and parasites which might infect man or domestic animals were recorded from bats under natural or experimental conditions and are presented in Table I.

It should be realized that all of the organisms mentioned will not produce symptoms when man or domestic animals become infected, for example, *Trypanosoma rangeli* does not produce symptoms in vertebrates.

The question marks in Table 1 indicate that no proof could be found in the literature that the organism may infect man or domestic animals, but that there is reason to believe that the organisms may do so under certain conditions.

Discussion

Because approximately half of the communicable diseases of man are Zoonoses it is logical to include both man and domestic animals in relation to the role that bats may play as a reservoir, intermediate host, vector or experimental animal for the organisms mentioned in the table.

KLITE (1965) showed that the food transit time of certain bats was less than 15 minutes and that they defecate about 60 times per day. Until recently, it was thought that bats were either insectivorous, frugivorous or hematophagous, but some investigators (ARATA et al. 1966) showed that the diet of various species is much more varied.

The contact that bats have directly or indirectly with man and domestic animals is much more frequent than formerly thought. For example many hematophagous arthropods such as mosquitos, ticks (PAVLOVSKY 1966) and cone-nosed bugs (BARRETTO 1968, FREITAS et al. 1960) feed on bats, domestic animals and man. Numerous species of bats shelter in human dwellings and even more species are peridomestic at night. The water, fruits and other crops used by animals and man, are frequently contaminated with feces of bats. Virologists think that bats might well serve as reservoirs for certain viruses during the time arthropod vector population is scarce, such as during winter and dry seasons. The contact of vampire bats with animals and man is well known. Due to the close proximity which bats often have with man and domestic animals it seems possible that they might play an important role in the epidemiology and transmission of some diseases.

Since the first isolation of *Histoplasma capsulatum* from bats in Panamá by KLITE & DIERKS (1965) and in Colombia by MARINKELLE & GROSE (1965), many more isolations have been reported from more than 30 species of bats in five different countries. *Trypanosoma cruzi* seems to be common in bats (MARINKELLE 1966) and can be transmitted to man or domestic animals by triatomid bugs. *Sporotrichum schenckii* first reported from bats by GROSE & MARINKELLE (1966) has been shown to occur frequently in these mammals (GROSE & MARINKELLE) as well as in cattle, horses and man.

An interesting finding is that the majority of Arbo viruses recorded from bats belong to CASAL's group B. It may be possible that the neutralizing antibodies of certain B viruses reported from bats by several authors are heterologous, due to the fact that some of the neutralizing antibodies produced by the host may be caused by infection with other group B viruses.

Only in recent years considerable interest has been created in examining bats for microorganisms other than viruses, and the results of these investigations have proven that these mammals harbor a large variety of pathogenic microorganisms.

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Table 1
Organisms transmissible to man or domestic animals and recovered from bats

Name of microorganism or parasite	"Group" or "Variety"	Infective to Man	Domestic animals	Literature references	Remarks
FUNGUS					
<i>Allesheria boydii</i>		+	+	48	few colombian bats
<i>Blastomyces dermatitidis</i>		+	+	140	experimental infection
<i>Candida albicans</i>		+	+	14, 48	from 2 continents
<i>Candida chiropterorum</i>		?	?	46	infects tissue cultures
<i>Candida parapsilosis</i>		+	—	33	american bats
<i>Candida tropicalis</i>		+	—	48	some colombian bats
<i>Cryptococcus neoformans</i>		+	+	47	9 colombian bats
<i>Geotrichum</i> spp.		+	—	48	many colombian bats
<i>Histoplasma capsulatum</i>		+	+	70, 83, 84	many colombian bats
<i>Horodendrum</i> spp.		+	+	48	many colombian bats
<i>Microsporium canis</i>		+	+	45	8 colombian bats
<i>Microsporium gypseum</i>		+	+	48	3 colombian bats
<i>Paracoccidioides brasiliensis</i>		+	—	49	5 colombian bats
<i>Torulopsis glabrata</i>		+	+	33	american bats
<i>Scopulariopsis</i> spp.		+	—	48, 81	many colombian bats
<i>Sporotrichum schenkii</i>		+	+	45, 84	84 colombian bats
<i>Trichophyton mentagrophytes</i>		+	+	45, 84	11 colombian bats
<i>Trichophyton persicolor</i>		+	?	38	1 english bat
<i>Trichosporum beigelli</i>		+	—	141	1 indonesian bat

Table 1
Organisms transmissible to man or domestic animals and recovered from bats (cont.)

Name of microorganism or parasite	"Group" or "Variety"	I n f e c t i v e t o		Literature references	Remarks
		Man	Domestic animals		
VIRUS					
Bangui — M 7	B	—	?	20	african bats
Bolivian hemorrhagic fever (Machupo arenovirus)	Tacaribe (L C M)	+	—	28	antibodies (?)
Bukalasa Bat	B	?	?	41, 147	african bats
Bunyamwera	Bun—C	+	?	107, 119, 121	antibodies only
Bussuquara	B	—	?	152	antibodies only
Caraparu	C	+	—	152	antibodies only
Catu	GMA	+	—	151, 152	brazilian bats
Chikungunya	A	+	?	119	antibodies only
Cocal	VSV	—	?	28	experimental infection
Coxsackie	Picornia	+	—	32	experimental infection
Dakar bat (I P D—A/249)	B	+	?	15, 16, 119	W. african bats
Dengue (I & II or IV)	B	+	—	28, 59, 96, 126	antibodies only
Eastern Equine	A	+	+	30, 31, 68, 126	experimental infection
Encephalomyelitis (E. E. E.)				151	and antibodies
Entebbe bat	B	—	?	75, 110, 121	E. african bats
Foot and Mouth Disease (F. M. F.)	(Rhino)	+	+	142	experimental infection
Guaroa	Bun	+	—	152	antibodies only
Ilheus	B	+	—	152, 136	experimental infection & antibodies

Table 1
Organisms transmissible to man or domestic animals and recovered from bats (cont.)

Name of microorganism or parasite	"Group" or "Variety"		I n f e c t i v e t o		Literature references	Remarks
	Man	Domestic animals	Man	Domestic animals		
Infections bronchitis	—	—	+	+	108	experimental infection cultures of bat tissues
Influenza — B	(Myxo-I)	+	?	?	66	antibodies only
Itaporanga	PHL	—	?	?	151, 152	experimental infection
<i>Herpesvirus simplex</i>	Herpes	+	—	—	105	experimental infection
Japanese B Encephalitis	B	+	+	+	30, 60, 73, 89 115, 129, 130 145	experimental infection & antibodies
Jurona	Bun	—	?	?	151, 152	antibodies only
Kern Canyon	(Rhabdo)	+	?	?	51, 64	bats in the U.S.A.
Kyasanur Forest Disease (K. F. D.)	B	+	?	?	98, 102, 126	indian bats
Lagos Bat	ungrouped	—	?	?	13	nigerian bats
Mayaro	A	+	—	—	127	colombian bats
Montana Myotis						
Leukoencephalitis (M. M. L.)	B	—	?	?	9	bats in the U.S.A.
Mount Elgan bat (MEB)	(Rhabdo)	—	?	?	88	from Kenya bat
Mount Suswa	B	—	?	?	55	from Kenya bat
Mucambo	A	+	+	+	152	antibodies only
Murray Valley Encephalitis (M. V. E.)	B	+	—	—	115, 123, 124, 128	antibodies only
Newcastle (<i>Myxovirus multiforma</i>)	Paramyxo	+	+	+	103, 109, 110	experimental infection
Ntaya	B	—	?	?	121	antibodies only

Table 1

Organisms transmissible to man or domestic animals and recovered from bats (cont.)

Name of microorganism or parasite	"Group" or "Variety"		I n f e c t i v e t o		Literature references	Remarks
	Man	Domestic animals	Man	Domestic animals		
Para influenza (para myxo)	+	?	+	?	99	bat from India
Pixuna	+	—	+	—	28	brasilian bat
Poliomyelitis	+	Lansing 2	+	—	106	experimental infection
Pseudorabies (<i>Herpesvirus suis</i>)	+	Herpes	+	+	104	experimental infection
Rabies	+	—	+	+	1, 18, 90	many isolates
Reo group	+	Type I	+	+	123	antibodies only
Río Bravo and Burns (bat salivary gland)	+	B	+	—	29, 63, 65, 131, 133	bats in the U.S.A.
S A H 336	+	B	+	—	119	from Uganda bat
Semliki Forest	+	A	+	—	107, 119, 120	antibodies
Sindbis	+	A	+	—	111	experimental infection
St. Louis Encephalitis	+	B	+	+	17, 126, 127, 128, 132, 152	american bats
Tacaiuma	—	—	—	?	152	antibodies only
Tacaribe (T C R) Areno	—	LCM	—	?	35	from bats Trinidad
Tembusu	—	B	—	?	28	antibodies only
Tick — borne Encephalitis (H Y P R)	+	B	+	—	52, 94, 126	antibodies only
Turkey menigo encephalitis	—	B	—	+	3	antibodies only
Turlock	—	Cal	—	?	152	antibodies only
Uganda S	+	B	+	—	5	antibodies only
Una	—	B	—	?	152	antibodies only

Table 1

Organisms transmissible to man or domestic animals and recovered from bats (cont.)

Name of microorganism or parasite	"Group" or "Variety"	I n f e c t i v e t o		Literature references	Remarks
		Man	Domestic animals		
Usuru	B	—	?	120, 121	antibodies only
Utinga	—	—	?	152	antibodies only
Venezuelan Equine Encephalitis (V. E. E.)	A (VSV)	+	+	30, 101, 144 139	Colombia, Mexico the U.S.A. antibodies only
Vesicular stomatitis	B	+	+	in 28	antibodies only
Wesselbron	B	+	+	3, 5, 120, 121, 126, 137	antibodies only
West Nile	—	+	+		
Western Equine Encephalomyelitis (W. E. E.)	A	+	+	28, 136	North & S. America
Yellow fever	B	+	—	5, 10, 72, 118, 126, 148	from 2 continents
Zika	B	+	—	5, 119, 121	antibodies only
Eight other yet unnamed	—	?	?	in 28	from 2 continents
RICKETTSIA					
<i>Coxiella burneti</i>	—	+	+	12, 76, 81	from 3 continents
<i>Rickettsia rickettsii</i>	—	+	+	79, 144	experimental infection
BACTERIA					
<i>Borrelia</i> see <i>Spirochaeta</i>	—	+	+		from 3 continents
<i>Escherichia</i> sp.	—	+	+	69	panamanian bats

Table 1

Organisms transmissible to man or domestic animals and recovered from bats (cont.)

Name of microorganism or parasite	"Group" or "Variety"		I n f e c t i v e t o		Literature references	Remarks
	Unidentified		Man	Domestic animals		
<i>Klebsiella-Aerobacter</i> <i>Serratia</i> group			+	+	69	panamanian bats
<i>Leptospira</i> type: <i>australis</i>			+	+	37	from bat kidneys antibodies only
<i>schüffneri</i>	Australis		+	+	58, 138, 146	indonesian bat
not typed	Canicola		+	+	87	colombian bat
<i>cynopteri</i>	Canicola		+	+	58, 138, 146	indonesian bat
<i>medanensis</i>	Cynopteri		+	?	57	malayan bat
<i>saxkoebing</i>	Hebdomadis		+	+	57	indonesian bat
<i>wolffi</i>	Hebdomadis		+	+	57	malayan bat
<i>sejroe</i>	Hebdomadis		+	+	28	experimental infection
not typed	Pomana		+	+	57	colombian bat
<i>Mycobacterium buruli</i>			+	—	21	experimental infection
<i>Mycobacterium leprae</i>			+	—	50	"hypothetic" infection
<i>Mycobacterium murinum</i>			+	—	25	experimental infection
<i>Mycobacterium tuberculosis</i>			+	+	33, 43, 44	bat kept in zoo
<i>Mycobacterium</i> sp. (<i>avium</i> ?)	bovine		+	+	33	bat from the U.S.A.
<i>Pasteurella pestis</i>	III		+	—	74, 100	experimental infection
<i>Pasteurella pseudotuberculosis</i>			+	+	58, 86	english bat
<i>Proteus</i> sp.			+	?	69	panamanian bats
<i>Pseudomonas</i> sp.			+	+	69	panamanian bats

Table 1

Organisms transmissible to man or domestic animals and recovered from bats (cont.)

Name of microorganism or parasite	"Group" or "Variety"	I n f e c t i v e t o		Literature references	Remarks
		Man	Domestic animals		
<i>Salmonella</i> serotypes:					
<i>anatium</i>		+	+	7, 138	colombian bat
<i>dar-es-salaam</i>	II	+	+	135	african bat
<i>blockley</i>		+	+	7, 138	colombian bat
<i>llandoff</i>		+	+	7, 138	colombian bat
<i>saintpaul</i>		+	+	71	panamanian bat
<i>sandiego</i>		+	+	7, 138	colombian bat
<i>typhimurium</i>		+	+	71	panamanian bat
<i>boydii</i>	Var. Copenhagen 2	+	—	7, 138	colombian bat
<i>Shigella boydii</i>		?	—	39	african bat
<i>Spirochaeta</i> (Syn. <i>Borrelia</i>)					
<i>Spirochaeta crocidurae</i>		+	—	19, 113	from 2 continents
<i>Spirochaeta duttoni</i>		?	—	4, 54	african bat
<i>Spirochaeta graingeri</i>		+	—	19, 39, 91	from 2 continents
<i>Spirochaeta hispania</i>		+	—	39	african bat
<i>Spirochaeta mazotti</i>		?	—	53	african bat
<i>Spirochaeta megadermae</i>		+	—	39	russian bats
<i>Spirochaeta persica</i>		+	—	93	experimental infection
<i>Spirochaeta recurrentis</i>		+	—	122	russian bat
<i>Spirochaeta slatyschewi</i> (Syn. <i>usbekistanica</i>)		?	—		
<i>Spirochaeta vesperillumis</i>		?	—	26, 42, 92	from 2 continents
<i>Spirochaeta</i> spp.		?	—	34, 85, 95, 97, 113, 117, 150	from 3 continents
<i>Yersinia enterocolitica</i>		+	+	143	experimental infection

Table 1

Organisms transmissible to man or domestic animals and recovered from bats (cont.)

Name of microorganism or parasite	"Group" or "Variety"		I n f e c t i v e t o		Literature references	Remarks
	Man	Domestic animals				
PROTOZOA						
<i>Besnoitia panamensis</i>	—	+	+		116	experimental infection
<i>Besnoitia jellisoni</i>	—	+	+		82	experimental infection
<i>Leishmania donovani</i>	+	+	+		77	experimental infection
<i>Toxoplasma gondii</i>	+	+	+		2, 28, 114	from 2 continents
<i>Trypanosoma cruzi</i>	+	+	+		80, 81, 84	many virulent strains
<i>Trypanosoma brucei (gambiense?)</i>	+	+	+		28, 134	african bat
<i>Trypanosoma congolense</i>	—	+	+		125	experimental infection
<i>Trypanosoma equinum</i> (Syn. <i>T. hippicum</i>)	—	+	+		23, 24, 36, 56, 61, 62	from vampire bats
<i>Trypanosoma equiperdum</i>	—	+	+		67	experimental infection
<i>Trypanosoma rangeli</i>	+	+	+		80	from Colombia
PLATYHELMINTHES						
<i>Heterophyes heterophyes</i>	+	+	+		78	from arabian bat
<i>Paralecithodendricum molenkampii</i>	+	?	?		57	indonesian bat
<i>Prosthodendrium ovimagnosum</i>	—	+	+		11	bat from India
<i>Hymenolepis nana</i>	+	+	+		82	colombian bats
NEMATODA						
<i>Trichinella spiralis</i>	+	+	+		22	experimental infection
"Numerous helminths"	+	+	+		28	spurious parasitism