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Disease relationships of arthropods in Africa with particular reference to mites and ticks

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Summary

Data obtained from the literature on disease relationships of different groups of arthropods (insects, mites and ticks) are summarized with the aid of tables. The involvement of mosquitoes as insect vectors in the transmission of malaria and other diseases has made this group of insects the most studied in Africa. A brief review of ticks as transmitters of pathogens is given. Recent research indicates that mites, a group which has not received adequate attention in Africa, but which has been incriminated in the transmission of disease in other parts of the world, may prove to be of comparable importance in Africa.

As Mattingly (1969) aptly put it, 'diseases are not just collections of signs and symptoms calling for treatment by a physician'. They can also be seen as ecological systems involving human populations and their physical and biological environment. This attitude inspires the hope not only of curing diseases when they occur, but also of preventing their occurrence.

Disease systems are often quite complicated and arthropod-borne diseases are especially more so because they involve an additional component, the arthropod vector, by which the disease is transmitted from one human host to another. Such a vector is itself subject to environmental hazards which determine whether it will live long enough for the pathogen which it is carrying to mature and become infective. Still more complicated are those diseases, called zoonoses, in which the pathogen is harboured by other animals as well as by man. A measure of the reality of the ecological aspect of disease is its frequent association with habitat.

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A number of criteria exist for incriminating a specific arthropod with transmission of the causal agents of disease. These criteria are summarized (Barnett, 1960) as follows: (a) a convincing biological association in time and/or space of the suspected arthropod species and occurrence of clinical or sub-clinical infection in the host. It must be emphasized, however, that temporal and/or spatial overlap of a certain arthropod and a disease, although providing valuable indications for experiments, is no proof of the arthropod as a vector; (b) a demonstration of the feeding and other effective contact with the host under natural conditions; (c) repeated demonstration that the arthropod, under natural conditions, harbours the infective agent in the infective stage; (d) transmission of a pathogen by an arthropod under laboratory conditions to any susceptible animal. However, transmission under such conditions can help only in delimiting potential vectors. On the other hand, suspect vectors can be exonerated in most cases if experimental transmission proves impossible.

By far the greatest amount of research work in the area of disease transmission by arthropods has been on mosquitoes. Data available in the literature on the mosquitoes include information on the biology of the larvae and adults in addition to distribution and disease relationships. The extremely diverse ecological conditions in Africa provide habitats that are occupied by well over 1000 species and sub-species. Naturally, there is more information on species that are of great economic importance (because they are disease vectors) than on less important and probably less common species (Smart, 1956; Gillies & De Meillon, 1968; Gillet, 1972).

The involvement of mosquitoes in the transmission of malaria among other diseases in many parts of the world has made the study of these insects a necessary priority. Malaria is still the most widely distributed disease in the world. In 1955 there were still 200–250 million cases with more than 2 million deaths. This obviously makes it the most lethal disease. It is transmitted by mosquitoes of the genus *Anopheles*. There are approximately 240 species of *Anopheles* known in the world and of this number, about sixty are the chief vectors of malaria.

In Africa, mosquitoes are also responsible for the transmission of yellow fever, dengue, Rift Valley fever, West Nile virus, Semliki Forest virus, encephalitis (Dick *et al.*, 1948), Sindbis virus (Woodall *et al.*, 1964), O'nyong-nyong virus (Haddow, Davis & Walker, 1960), Bunyamwera virus (Smithburn, Haddow & Mahaffy, 1946), Bwamba virus (Smithburn, Mahaffy & Paul, 1941), etc.

Data on disease-relationships and the distribution in Africa of *Anopheles*, *Aedes*, *Culex* and other groups of mosquitoes are summarized in Tables 1–3.

Other dipterans of medical importance include blackflies, sandflies, biting midges, tabanids, tsetse flies and a host of non-biting flies.

Simulium damnosum transmits onchocerciasis or 'river blindness' in different parts of Africa (Geigy & Herbig, 1955; Kirk *et al.*, 1959; Wyatt, 1971). *Simulium neavei* is also incriminated in the transmission of the same disease in Zaïre (Freeman & de Meillon, 1953; Grenier & Mouchet, 1958) and Uganda (Barnley, 1958; 1962). However, most of the records of blackflies concern distribution.

Amongst the sandflies (Fam. Psychodidae), several species belonging to the large genus *Phlebotomus* are implicated in the transmission of disease. In North Africa *Phlebotomus longicuspis* transmits cutaneous leishmaniasis (Sergent & Sergent, 1949; Geigy & Herbig, 1955). *Phlebotomus papatasi* transmits sandfly fever as well as cutaneous leishmaniasis in the Sudan (Lewis & Kirk, 1951, 1954; Hoogstraal & Dietlein, 1963; Lysenko, 1971).

Biting midges (Fam. Ceratopogonidae) are vectors of several pathogenic organisms. A concise account of their role in this regard has been given by Kettle (1965). A number of species of the genus *Culicoides*, namely, *Culicoides austeni*, *C. grahami*, *C. jouberti* and *C. tristanii* are recorded as vectors of *Dipetalonema perstans* and *D. streptocerca* in West and Central Africa, including Tanzania (Ingram & Macfie, 1921, 1923, 1924).

The virus of Bluetongue, an important disease of sheep, is transmitted by *Culicoides pallidipennis* in Africa, although recent investigations (Walker & Davies, 1971) also incriminate *C. tororoensis* and *C. milnei*. Undetermined species of *Culicoides* are probably involved in the transmission of the virus of African horse sickness (Du Toit, 1944), a disease which in recent years has extended into Pakistan and other parts of the Middle East, where it has taken a heavy toll on horses and mules. Furthermore, some workers (Huttel, Huttel & Verdier, 1953; Wanson, 1939) believe that *Culicoides jouberti* and *C. tristanii* transmit 'African dengue'. However, experimental verification would be required to confirm this.

Recently, six arboviruses of the Simbu group, four of them previously unknown, were isolated in Ibadan from cattle, sheep, goat, *Culicoides* and man (Causey *et al.*, 1972).

Tabanids (horse flies), particularly species of *Chrysops*, are notorious for their role in the transmission of Loa loa as follows: *Chrysops centurionis* in Nigeria, *C. dimidiata* in Nigeria and Zaïre, *C. distinctipennis* and *C. longicornis* in Sudan, *C. silacea* and *C. zahrai* in Nigeria (Woodman, 1949; Crewe, 1955; Duke, 1958).

Amongst the biting flies nearly all the important species involving man belong to the genus *Glossina*. Tsetse fly species such as *Glossina palpalis*, *G. morsitans* and *G. tachinoides* play a leading role in the transmission of trypanosomiasis or sleeping sickness in different parts of Africa (Soltys, 1971). Recently, a joint F.A.O/W.H.O. Expert Committee on African trypanosomiasis* concluded that trypanosomiasis is a major factor in holding back the development of many areas of Africa south of the Sahara. Other recorded species that transmit sleeping sickness are *Glossina fuscipes* in Central Africa, *G. longipalpis* in West Africa and *G. pallidipes* in East Africa. *Stomoxys calcitrans* is recorded as causing human myiasis in the Cape Verde Islands.

A number of non-biting flies, including species of *Calliphora*, *Aphiochaeta*, *Chrysomyia*, *Cordylobia*, *Fannia*, *Gasterophilus*, *Lucilia*, *Musca*, *Oestrus*, *Sarcophaga*, *Stasisia* and *Wohlfahrtia*, cause different types of myiasis.

Little is known of the role played by fleas as disease vectors in Africa. *Xenopsylla cheopsis* is, however, known to transmit bubonic plague from wild rodents in different parts of the continent. In Morocco and Senegal *Xenopsylla astia*, *X. braziliensis*,

* Joint F.A.O./W.H.O. Expert Committee on African trypanosomaiasis (1969) *Report*, Geneva (*Wld Hlth Org. techn. Rep. Ser.*).

TABLE 1. Mosquitoes (anopheles group)

Arthropod vector	Disease or disease organism	Locality
Anopheles algeriensis	Malaria	Tunisia
	Nocturnal filariasis	Tunisia
A. austenii	Malaria	Ghana
A. brunnipes	Malaria	Zaïre, Ghana
A. claviger	Malaria	Morocco
A. costalis	Malaria	Zaïre, Tanzania
	Wuchereria bancrofti	Nigeria, Cameroons
A. funestus	Malaria	All Africa, Malagasy Republic
	Bwamba	Uganda, Nigeria
	O'nyong-nyong	Kenya, Uganda
	Wuchereria bancrofti	Kenya, Tanzania
A. funestus funestus	Filiaria	Zaïre
A. gambiae	Malaria	All Africa
	Wuchereria bancrofti	Kenya, Tanzania
	Filaria	Mozambique, Malagasy Republic
	O'nyong-nyong	Uganda
	Nyando grp. virus	Nigeria
	Bunyamwera grp. virus	Nigeria
A. hancocki	Malaria	Ghana, Liberia
A. maculipalpis	Malaria	Republic of South Africa
	Wuchereria bancrofti	Malagasy Republic
	Filaria	Malagasy Republic
A. hargreavesi	Malaria	Ghana, Liberia
A. hispaniola	Malaria	Tunisia
A. labranchiae	Malaria	Algeria, Morocco, Tunisia
A. maculipennis	Malaria	Tunisia
A. maculipennis labranchiae	Malaria	Tunisia
A. marshalli var. *gibbinsi*	Malaria	Uganda, Ghana
A. marshalli var. *moucheti*	Malaria	Zaïre
A. melas	Malaria	Ghana, Liberia
A. moucheti	Malaria	Ghana, Uganda
A. moucheti nigeriensis	Malaria	Ghana
A. multicolor	Malaria	Algeria, Tunisia, Egypt
A. nili	Marsh fever	Gambia
	Malaria	Sudan, West Africa, Zaïre
A. paludis	Malaria	Zaïre
A. pharoensis	Malaria	Sudan, Ethiopia, Ghana Malagasy Republic, Republic of South Africa, Tanzania
A. pretoriensis	Malaria	Ethiopia, Ghana
A. rhodesiensis	Malaria	Ethiopia
	Wuchereria bancrofti	Ghana
	Nocturnal filariasis	Sierra Leone, Tanzania
A. rufipes	Malaria	Sudan, Upper Volta
A. sergentii	Malaria	Libya, Egypt
A. squamosus	Malaria	Malagasy Republic
	Wuchereria bancrofti	Sierra Leone, Ghana, Malagasy Republic
	Nocturnal filariasis	Sierra Leone, Tanzania
A. theileri var *hancocki*	Malaria	Uganda

TABLE 2. Mosquitoes (aedes group)

Arthropod vector	Disease or disease organism	Locality
Aedes aegypti	Yellow fever	Sudan, Ethiopia, West Africa
	Semliki Forest virus	Republic of South Africa
	Dengue	Ethiopia, Gabon, Nigeria
	Chikungunya virus	Rhodesia, Nigeria
	Filariasis	Malagasy Republic
A. aegypti var. *queenslandensis*	*Wuchereria bancrofti*	Nigeria, Tanzania
	Chikungunya virus	Rhodesia
A. africanus	Yellow fever	East Africa
A. argenteus	Yellow fever	Senegal
	Dengue	Republic of South Africa
	Wuchereria bancrofti	Republic of South Africa
A. caballus	Rift Valley fever	Republic of South Africa
A. luteocephalus	Yellow fever	Sudan, Gambia
	Dengue	Nigeria
	Zika virus	Nigeria
A. simpsoni	Yellow fever	Gambia, Ghana, East Africa
A. simpsoni lilii	Yellow fever	Sudan
A. vittatus	Yellow fever	Sudan, Gambia
A. circumluteolus	Bunyamwera virus	Uganda
	Bwamba virus	Uganda
	Pongola etc. virus	South Africa

TABLE 3. Mosquitoes (culex group and others)

Arthropod vector	Disease or disease organism	Locality
Culex fatigans	*Wuchereria bancrofti*	Malagasy Republic, East Africa, Nigeria
	Filaria	Malagasy Republic
C. pipiens	*Wuchereria bancrofti*	Egypt
C. pipiens fatigans	*Wuchereria bancrofti*	Zaïre, Kenya
	Nocturnal filariasis	Egypt, Kenya, Tanzania
C. thalassius	Yellow fever	Gambia
C. univittatus	West Nile virus	Egypt, Sudan, Zaïre, Uganda
	Sindbis virus	Egypt
Eretmapodites chrysogaster	Yellow fever	Senegal
Mansonia africana	Yellow fever	Sudan
	Nocturnal filariasis	Tanzania
	Bwamba virus	Uganda

X. eridos and *Pulex irritans* are also involved in the transmission of bubonic plague. In the Republic of South Africa where this group has been well studied, the following species are implicated in the transmission of plague: *Ceratophyllus fasciatus, Chiastopsylla rossi, Ctenocephalus canis, Dinopsyllus lypusus, Leptosylla musculi, Xenopsylla braziliensis, X. cheopsis* and *X. eridos*.

Some lice are recorded as being disease transmitters. *Pediculus humanus*, occurring in different parts of the world, is the vector of *Borrelia recurrentis*, the causative agent of relapsing fever, in parts of Africa. It is also recorded in North Africa and in Zaïre as transmitting *Rickettsia prowazekii* (causative agent of typhus). In Kenya *Pediculus humanus corporis* is recorded as transmitting Kenya spirochaete (believed to be related to *Spirochaeta carteri*). It is also implicated in the Republic of South Africa (Brain, 1929) in the transmission of epidemic typhus and typhus fever. *Pediculus vestmenti* is also recorded from North Africa and Zaïre as a vector of *Borrelia recurrentis*.

TABLE 4. Ticks and Mites

Arthropod vector	Disease or disease organism	Locality
Haemaphysalis leachi	tick-borne typhus	Republic of South Africa, Zaïre
Rhipicephalus appendiculatus	tick-borne typhus	Uganda, Republic of South Africa
	African Coast fever	Tanzania
R. sanguineus	relapsing fever	Ethiopia
	tick-bite fever	Kenya, Malawi
R. pravus	Kadam virus	Uganda
R. simus	tick paralysis	Ethiopia
Ixodes rubicundus	tick paralysis	Republic of South Africa
Amblyomma variegatum	Dugbe virus	Nigeria, Uganda
	Congo virus	Nigeria
	Bhanja virus	Nigeria
	Thogoto virus	Nigeria
A. lepidum	Dugbe virus	Uganda
A. hebraeum	tick-borne typhus	Republic of South Africa
Boophilus decoloratus	tick-borne typhus	Malawi, Republic of South Africa
	Dugbe virus	Nigeria
	Bhanja virus	Nigeria
	Congo virus	Nigeria
	Thogoto virus	Nigeria
Hyalomma truncatum	Dugbe virus	Nigeria
	Bhanja virus	Nigeria
	Congo virus	Nigeria
	Thogoto virus	Nigeria
	tick paralysis	Republic of South Africa
H. rufipes	Dugbe virus	Nigeria
	Congo virus	Nigeria
H. excavatum	Congo virus	Nigeria
H. impeltatum	Congo virus	Nigeria
Ornithodoros erraticus	*Spirochaeta hispanica*	Algeria, Morocco
	Spirochaeta normandi	Tunisia
	Spirochaeta diplodilli	Kenya
O. erraticus var. *marocanus*	Dakar relapsing fever	Senegal
Ornithodoros foleyi	tick-bite fever	Algeria, Libya
Ornithodoros moubata	*Spirochaeta duttoni*	Malagasy, Republic of South Africa
Ornithodoros moubata	African relapsing fever	Angola, Zaïre, Malawi, Somali, Kenya, Republic of South Africa
	Borrelia duttoni	Botswana, Malagasy, Tanzania
	Human spirochaetosis	Malagasy
Ornithodoros normandi	*Spirochaeta normandi*	Tunisia
Ornithodoros sp.	relapsing fever	Ethiopia, Kenya
Argas arboreus	Quaranfil virus	Egypt
A. reflexus hermanni	West Nile virus	Egypt
Tarsonemus hominis	parasite found in spinal fluid	Morocco
Pediculoides ventricosus	Dermatitis	Morocco
	Erythema	Algeria
Eotetranychus telarius	Dermal erythema	Algeria
Allodermanysus sanguineus	rickettsialpox	Republic of South Africa?
Ornithonysus bacoti	rickettsialpox, murine typhus, plague, dermatitis	Republic of South Africa

The literature on urticating and vesicating arthropods in Africa is surprisingly scanty. Nevertheless, species of *Cantharis* and *Epicauta* are recorded as causing vesicular dermatitis. *Paederus crebrepunctatus* causes conjunctivitis and blister on various parts of the body.

The comments made so far have concerned insects of medical importance. In the light of more recent research, other arthropods have become of increasing importance from the point of view of their disease relationships. These belong to the Acarina—a group which includes the ticks and mites.

The special importance of ticks to livestock in Africa from the point of view of disease transmission is well known (Hoogstraal, 1956; Bedford, 1934; Matthysse, 1954; Theiler, 1962; Arthur, 1962; Karrar, 1960, 1966, 1967; Uilenberg, 1971; Eastwood 1971). They are also involved in the transmission of some serious human pathogens especially viral and rickettsial diseases (Hoogstraal, 1966, 1967).

The Crimean haemorrhagic fever (CHF) virus, which is present in humans and animals in many areas of Southern U.S.S.R., Czechoslovakia, Bulgaria and Yugoslavia is associated with the bite of the tick *Hyalomma marginatum* Koch. This tick occurs in a widespread complex, members of which infest birds readily and may be transported to nearby localities and even to Africa from Asia and Europe. Small foci of the Eurasian subspecies *marginatum* occur in Africa and of the African subspecies *rufipes* in U.S.S.R., while larvae and nymphs of the subspecies *marginatum* are transported by birds to Finland and Africa (Casals *et al.*, 1966). It is most interesting, therefore, that Congo virus, previously known to be associated with infections of man and cattle in the Congo and parts of East Africa, (Woodall, Williams & Simpson, 1967) and recently isolated in Nigeria from *Hyalomma rufipes* and other ixodid ticks (Causey *et al.*, 1970), has been shown (Casals, 1969) to be antigenically indistinguishable from the causative agent of CHF in Russia and Bulgaria (Chumakov *et al.*, 1964).

Isolations of the West Nile virus from the soft tick *Argas reflexus hermanni* Andouin in pigeon cotes of the Nile delta suggest a means of overwintering as well as a more lasting reservoir (Schmidt & Said, 1964).

A considerable amount of work including collection of ticks and the processing of them for viral agents has been carried out in the Virus Research Laboratory at the University of Ibadan, Nigeria. In the period 1964–1968 there have been 647 virus isolations from ixodid ticks collected from livestock in Nigeria. Although five viruses have been recovered from ticks in West Africa, the isolations made in Ibadan belong to four serological groups and the viruses were identified as Dugbe virus (464 strains), Bhanja (92), Thogoto (64) and Congo (27) (Causey *et al.*, 1970, 1971a & b; Williams, Causey & Kemp, 1972). All these four viruses were recovered from additional sources during the same period: Dugbe, from man, trade cattle, sentinel calves, and *Culicoides* spp.; Bhanja, from trade animals; Thogoto, from man and trade cattle; and Congo, from trade animals, African hedgehog, *Atelerix albiventris*, and *Culicoides* spp. The new type, Dugbe virus, was present in a significant number of tick pools (largely of *Amblyomma variegatum* (F.)) and in cattle bloods. It was also isolated from a man infected in the laboratory and from a febrile child. The Bhanja- and Thogoto-type viruses were obtained mainly from pools of *Boophilus decoloratus* (Koch). It is important to note that the two species, *Amblyomma variegatum* (F.) and *Boophilus decoloratus* (Koch), are predominant on cattle in Nigeria. Bhanja virus has been isolated from cattle and sheep and Thogoto virus from cattle and from two humans with neurological symptoms, one of whom died of meningitis. Congo virus has been isolated from a febrile cow and it is capable of causing severe human illness and death (Woodall *et al.*, 1967). The fifth virus, Bandia (Bres, Cornet & Robin, 1967), is known only from collections in Senegal.

The East African Virus Research Institute at Entebbe, Uganda, continues to isolate new viruses from ticks, particularly from *Amblyomma variegatum* and *A. lepidum* Doenitz (Williams, 1968; Tukei *et al.*, 1970). With the recognition of Kadam virus from *Rhipicephalus pravus* Doenitz (Henderson *et al.*, 1970), the African continent becomes involved for the first time in the distribution of this group.

Although recovery of the viruses indicates that disease relationships do exist, it is clear that much more work is required in this field. The rate of discovery of new tick-borne agents is increasing considerably in Africa and, no doubt, many more await discovery.

Mites are among the commonest ectoparasites (both in numbers and kind) of warm-blooded animals and their dwelling places. Under experimental conditions mites are known to be capable of transmitting agents from nearly every major group of microbial pathogens: bacteria, rickettsiae, viruses, spirochaetes, protozoa and helminths.

Despite the fact that parasitic mites are known to play a role in disease transmission in other parts of the world (Blake *et al.*, 1945, Traub, Frick &

Dierks, 1950; Yunker, 1964, Horsefall & Tamm, 1965), available information on the disease relationships of mites in Africa is comparably scanty. This is attributable largely to the fact that the African fauna (especially the West and Central African) is still poorly studied. The immature stages of only a few species are known, and field collected larvae and nymphs from anywhere in Africa can seldom be accurately identified. This is an obvious deterrent to efforts to evaluate the disease relationships of mites.

The itch mite, *Sarcoptes scabiei* is known to cause dermatitis in man. *Allodermanyssus sanguineus* which parasitizes synanthropic rodents, mainly *Mus musculus*, is also a facultative biter of man and the proven vector to man of the rickettsialpox organism in North America. It was found on *Mus musculus* and on *Acomys cahirinus* in the Sudan (Keegan, 1956). There is serological evidence that this disease also occurs in South Africa, where it is probably transmitted by *Ornithonyssus bacoti* (Zumpt *et al.*, 1961).

The tropical rat mite *Ornithonyssus bacoti*, found on domestic rats especially *Rattus rattus* is, under experimental conditions, a good transmitter of rickettsialpox as well as a number of important human diseases including murine typhus and plague (Dove & Shelmire, 1932; Yamada, 1932; Philip & Hughes, 1948; Hopla, 1951). In South Africa where *O. bacoti* frequently infests the house mouse, *Mus musculus*, it has been recorded several times as causing outbreaks of dermatitis among humans, especially in factories which are heavily infested with domestic rats (Zumpt *et al.*, 1961). The report of the isolation from *Laelaps* (*Echinolaelaps*) *echidninus* of the Junin virus, causative agent of Argentinian haemorrhagic fever (Parodi *et al.*, 1959), is interesting from the point of view of the fact that this mite is frequently associated with the ubiquitous house rat, *Rattus rattus*.

As a necessary step towards the provision of data required for the elucidation of disease relationships of parasitic mites, emphasis has to be laid on the study of mite taxonomy, ecology, biology and disease epidemiology.

A study of the fauna and ecology of gamasid mites parasitic on birds and small mammals in Ibadan and environs, Western Nigeria (1967–1973) has led not only to the description of some new mites (Okereke, 1968, 1973) but also to the expansion of the mite fauna from ten poorly known species to twenty-five species (Okereke, 1970) together with data on distribution, ecology, seasonal dynamics, host preferences and the nature of association of these bloodsucking mites with their hosts (Okereke, 1971).

Of the total number (1011) of trapped small mammals, consisting mainly of rodents and insectivores, 69·9% were infested with gamasid mites. A total of 9574 mites was collected off these hosts. The degree of infestation of different host species ranged from light to very-heavy. It was also discovered that some mite species show a definite predilection to certain host species.

It is clear in the area of study that some species of wild rodents often find their way into human habitations or public buildings or are often in close proximity to these. This is probably due to the poor housing conditions in the rural areas which in turn can be related to the low level of development as well as to the farming habits of the local people. Furthermore, the human population explosion has resulted in exploitation and occupation of vast areas of forest, not previously influenced by serious human activity and where man will come in contact with wild rodents. From an epidemiological standpoint wildlife reservoirs are a very important source for vector infection with pathogens causing human disease. Thus man is often merely only a tangential host in a normal cycle involving other vertebrates which are unaffected by arthropod-borne pathogens.

A comparison of material collected in four localities offering reasonably different ecological conditions, namely: two forest habitats, one fallow land and one cassava field did not reveal any significant difference either in the species composition (i.e. with respect to each individual host animal) or in the number of mites per host. Thus the distribution of bloodsucking mites on small mammalian and avian hosts in Western Nigeria and probably other parts of Africa is determined mainly by the kind of association between the parasites and their hosts.

One fact that clearly emerges from these investigations in Western Nigeria, however, is that the local conditions in the areas of study still provide maximum opportunities for contact between the mites, animal reservoirs and man. Given such a situation, the significance of parasitic mites as potential vectors of human pathogens should not be underestimated. Finally, it is generally true that relatively few laboratories are devoted to investigation of mite-borne disease agents. Therefore, a large part of the significance of parasitic mites to human and animal health still awaits to be evaluated.

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