Viruses other than arenaviruses from West African wild mammals

Factors affecting transmission to man and domestic animals

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At least thirty-seven different viruses have been isolated from wild mammals in West Africa since 1962. Some of these, including Lassa virus, are already known to cause serious human morbidity and mortality. Crimean haemorrhagic fever-Congo virus, Dugbe virus, Mokola virus, and a smallpox-like agent from a gerbil in Dahomey are briefly discussed. An account of social and ecologic factors affecting man, domestic animals, and their interaction with wild mammals is given.

HISTORY AND INTRODUCTION

Serious virus research in British West Africa began with the formation of the Africa Yellow Fever Commission of the Rockefeller Foundation in 1925 and the isolation of yellow fever virus by inoculating Indian rhesus monkeys with blood from infected humans in 1927 (22). Similar experiments in Dakar by French workers confirmed and extended these findings (14). Testing of African mammals for susceptibility to yellow fever virus continued through the 1930s, primarily in subhuman primates, although a few additional nonprimate species were examined.

Concerted efforts to assess the importance of small mammals as natural hosts of virus infections in West Africa commenced during 1962 when the Institut Pasteur in Dakar, Senegal, began examining large numbers of insectivorous bats for the presence of virus. In 1964, a virus research laboratory (VRL) was established by the Rockefeller Foundation in Ibadan, Nigeria. During the next 10 years, many thousands of wild animals were examined by these two laboratories, and this work resulted in numerous isolations of viruses (Table 1).

Some of these newly isolated agents have been shown to infect man and domestic animals in natural cycles; many others have not been sufficiently studied to assess their importance. Only those agents actually isolated from wild mammals have been listed in Table 1. Numerous other viruses already isolated from arthropod vectors, from man, from domestic animals in West Africa, and from various sources in other African countries will undoubtedly be shown to have a natural cycle involving small mammals, and this cycle will ultimately be found to occur in West Africa as well.

The purpose of this paper is to compile information on the current status of wild mammal viral isolations in West Africa and to discuss factors influencing transmission of these agents to man and his domestic animals.

ECOLOGICAL CONSIDERATIONS

A combination of vegetation, soil, and meteorology controls animal distribution (6). In West Africa, at least 8 ecologically distinct vegetative zones have an important effect on wild mammal populations and their distribution. From the south, proceeding inland, these ecologic zones, which vary in dimensions, are mangrove forest and coastal vegetation, montane, freshwater swamp, lowland rain forest, Southern Guinea, Northern Guinea, Sudan and Sahel zones (9). Annual rainfall varies from 254 cm (100 in) on the coast to less than 25 cm (10 in) in the Sahel zone. More rain is needed to keep the ground moist in the tropics because evaporation rates are higher and tropical soils do not retain water well. As the quantity of rain decreases northward from the equator, the variability of rainfall increases. The total amount is less, and the rainy season is shorter. Climate averages are less impor-

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Table 1. Wild animal viral isolates from West Africa and Cameroon

Country	Virus group	Virus	Date of first isolation in country	Animals from which isolates obtained and no. of isolates	References
Nigeria	Group A	Dakar bat	25 January, 1966	*Tadarida condylura* (3)	3
		Semliki Forest	29 May, 1970	*Atelerix albiventris* (1)	13
	Group B	Uganda S	20 May, 1966	*Arvicanthis niloticus* (1) *Cricetomys gambianus* (1) *Mastomys natalensis* (1)	13
		West Nile	2 March, 1965	*Arvicanthis niloticus* (2)	13
	Phlebotomus fever	Arumowot	7 December, 1966	*Thamnomys macmillani* (1) *Arvicanthis niloticus* (3) *Tatera kempii* (1) *Crocidura sp.* (1)	13
		Sud An 754/61	19 May, 1966	*Cricetomys gambianus* (3) *Mastomys natalensis* (1) *Tatera kempii* (2) *Arvicanthis niloticus* (26) *Galago senegalensis* (2) *Atelerix albiventris* (2) *Taterillus gracilis* (5)	13
	Vesicular stomatitis	Chandipura	9 May, 1966	*Atelerix albiventris* (1)	13
	Rabies serogroup	Mokola	8 May, 1968	*Crocidura* sp. (4)	11, 19
		Lagos bat	1958	*Eidolon helvum* (1 pool)	1
	CHF-Congo	CHF-Con.	2 September, 1964	*Atelerix albiventris* (2)	4, 13
	Bluetongue	Bluetongue, type 7	15 November, 1967	*Crocidura* sp. (1)	13
	Nairobi sheep disease	Dugbe	2 September, 1964	*Cricetomys gambianus* (1)	13
	Arenavirus	Lassa	5 December, 1972	*Mastomys natalensis* (5) *Mus* sp. (1) *Rattus rattus?* (2)	H. Wulff, 1975, personal communication
	Ungrouped	Bhanja	10 November, 1964	*Atelerix albiventris* (1) *Xerus erythropus* (1)	13
		Lebombo	10 November, 1967	*Thryonomys swinderanus* (1)	13
		IbAn 17143	23 January, 1967	*Atelerix albiventris*	13, R. E. Shope, 1975, personal communication
		IbAn 57204	9 April, 1971	*Eidolon helvum* (7)	R. E. Shope, 1975, personal communication
		IbAn 50991	23 December, 1969	*Crocidura* sp. (1)	R. E. Shope, 1975, personal communication
Dahomey	Phlebotomus fever	Sud An 754/61	17 April, 1968	*Taterillus* sp. (5) *Mastomys natalensis* (1) *Cricetomys gambianus* (1) *Lemniscomys* sp. (1) *Tatera kempii* (4)	13
	Poxvirus	Tatera pox IbAn 34325	23 April, 1969	*Tatera kempii* (1)	13, 23
	Ungrouped	IbAn 33709	18 April, 1968	*Tatera kempii* (1)	13, R. E. Shope, 1975, personal communication
Sierra Leone	Arenavirus	Lassa	September, 1972	*Mastomys natalensis* (14)	16
Senegal	Group A	Chikungunya	December, 1962	*Scotophilus* sp. (1) *Cercopithecus aethiops* (1) *Galago senegalensis* (1)	Y. Robin, 1975, personal communication

Table 1 (*continued*)

Country	Virus group	Virus	Date of first isolation in country	Animals from which isolates obtained and no. of isolates	References
Senegal (cont.)	Group B	Koutongo	April, 1968	*Tatera kempii* (1) *Mastomys natalensis* (1)	Y. Robin, 1975, personal communication
		Dakar bat	September, 1962	*Scotophilus* sp.	Y. Robin, 1975, personal communication
		Saboya	February, 1968	*Tatera kempii*	Y. Robin, 1975, personal communication
		Bouboui	December, 1972	*Papio papio*	Y. Robin, 1975, personal communication
		Bukalasa bat	March, 1965	*Tadarida* sp.	Y. Robin, 1975, personal communication
	Phlebotomus fever	Sud An 754/61	April, 1962	*Tatera kempii* (1) *Taterillus* sp. (1)	Y. Robin, 1975, personal communication
	Qalyub	Bandia	February, 1965	*Mastomys natalensis* (1) *Xerus erythropus* (1)	2; Y. Robin, 1975, personal communication
	Ungrouped	Gossas	November, 1964	*Tadarida* sp. (1)	Y. Robin, 1975, personal communication
		Toure	February, 1968	*Tatera kempii* (1)	Y. Robin, 1975, personal communication
		Keuraliba	April, 1968	*Tatera kempii* (1) *Taterillus* sp. (1)	Y. Robin, 1975, personal communication
		Yogue	June, 1968	*Roussettus aegypticus* (1)	Y. Robin, 1975, personal communication
Cameroon	Group B	Y 589	May, 1972	Monkey (1) Antelope (1)	Y. Robin, 1975, personal communication
	Herpes	YV 6	April, 1971	*Eidolon helvum* (1) Lemur (1)	Y. Robin, 1975, personal communication
	Ungrouped	DakAr YV 177	May, 1971	*Eidolon helvum* (1)	Y. Robin, 1975, personal communication

tant than extremes, and these extremes of temperature, rainfall, and humidity increase in the near-desert zones. Microclimates are of greater importance in these areas than in the southern rainforest areas, and hence holes, burrows, caves, and rock fissures form the natural habitat of many animals seeking more stable environmental conditions for life (6).

Abundance of animal species with small stable populations is the rule in the humid rainforest where ideal conditions for animal life occur. Extremes of temperature, rainfall, and humidity in the arid regions have an opposite effect, causing greater fluctuations in animal populations.

INTERVENTION BY MAN

In his desire to mechanize farming and increase industrial potential, man is rapidly changing animal habitats in West Africa, particularly in the vicinity of large population centres. Very little virgin forest exists in West Africa because of the slash-and-burn type of agriculture practised in the forest zone, the replacement of forest with oil palm and rubber plantations, and the extensive logging operations (9, 15). The arid areas of the northern zones have not escaped the human and domestic animal population pressures. Extensive overpopulation of these areas by man and animals has led to overgrazing and vast destruction of perennial grasses. The introduction of bore-hole wells has further increased pressures by allowing greater numbers of domestic animals to survive and destroy more grazing lands, thus increasing the rate of sand drifting (18). The lack of rain in the Sahel Zones in recent years has led to a vast die-off of domestic animals, the failure of crops, and human starvation, and has necessitated vast international relief efforts (21).

Man's interventions and destruction of habitat necessarily have a profound effect on animal populations by creating imbalances in the natural flora and fauna of these areas. It can be expected that this intrusion will involve man in situations where he may acquire more viral infections of wild animals. The effects of irrigation schemes and the impoundment of water have not been studied sufficiently to assess their potential impact on animal populations, virus amplification, and vector abundance in West Africa.

Nomadic tribes in company with cattle, sheep, goats, and camels traverse vast areas of West Africa in seasonal migrations with the aims of seeking improved seasonal grazing, avoiding the tsetse fly, and marketing animals at human population centres in the south (10). In these treks, the nomads cross a number of ecologic zones, transport viruses and vector ticks, and provide blood meals for other vectors *en route* (12). The potential for transporting and amplifying virus and the involvement of other vertebrates along these trade routes has not been sufficiently studied.

HUMAN CONTACT WITH WILD ANIMALS

Industry is not well developed in West Africa; although cities are growing rapidly, the bulk of the population is still engaged in subsistence farming in rural areas. Farmers continue to have intimate contact with wild animals, particularly the small ones, in their everyday pursuits. " Bush meat ", which includes the smallest animals and birds, is an important source of protein for most, if not all, rural peoples. Some of the larger rodents are considered to be food delicacies and are transported long distances to meet the protein demands of the cities (13). Housing in West Africa varies in structure, but practically none is animal proof. Bats frequently inhabit thatched roofs and attics if such are available. Some types of housing, such as that using criss-cross hollow bamboo poles covered by mud, provide excellent harborage for small mammals in house walls, particularly as the house ages and the bamboo septa disintegrate. Small mammals, including rodents and insectivores, gain easy access to houses as they readily burrow under foundations or through mud walls. West African kitchens are commonly shared by the several related family groups using the same compound and they serve as food storage areas for roots, fruits, and grains (16). Rarely is food protected from animal incursions. The presence of rodents that eat grain and vegetable roots serves to attract small wild carnivores and insectivores to these houses and kitchens (11). It has been observed that this situation is particularly acute at the end of the harvest, during the dry season, when animal food becomes scarce in the fields and is brought into the villages.

It should be noted that 17% of 7497 animals examined in Nigerian studies were *Mastomys natalensis*, and these rodents are equally at home in villages and the field (13). This animal has already been shown to be naturally infected by Lassa virus (16). Similarly, shrews (*Crocidura* sp.) are commonly found in households; they comprised 7% of animals sampled in Nigeria. These animals harbour Mokola virus, a new rabies-related virus shown to be capable of causing human illness and death (8, 11, 19).

The virus of Crimean haemorrhagic fever-Congo has been isolated twice from the African hedgehog in widely separated parts of Nigeria and on numerous occasions from livestock and ticks but has not yet been incriminated as the cause of human disease in West Africa (4). However, this virus has caused serious disease in Zaire and epidemics with high mortality rates in East Africa (20) and the USSR (7).

Dugbe virus (5), the most common isolate at the Ibadan Laboratory, was obtained in most instances from ticks and livestock. It was isolated on one occasion from the giant rat *Cricetomys gambianus* (13) and on 4 occasions from ill persons in that country (17). A smallpox-like agent isolated from a healthy gerbil during a smallpox epidemic in Dahomey could have serious future implications for man in West Africa (23).

In cities, open sewers, poorly regulated refuse disposal, and inadequately stored food have caused sizable small mammal populations to adapt to an urban existence. Rodents and shrews abound, and some of the same conditions promote intimate contact between man, wild animals, and numerous arthropod vectors. Furthermore, piped water is usually not provided on an individual household basis, and this necessitates household storage of water in a variety of earthen pots, barrels, buckets, etc. These are frequently contaminated by small mammals and also serve as breeding places for arthropods.

FUTURE RESEARCH

Numerous factors concerned in the population dynamics, distribution, identification, speciation, and intermingling of small mammals in West Africa, and parasite and vector preferences for these animals, remain unknown or poorly understood.

Expanded and intensified taxonomic and ecological studies, such as the Pan African mammal study conducted by the Smithsonian Institution, need support. If funds were increased, these studies could also include parasitological and virological examination of captured animals. Such work requires well-trained field teams; these should be immunized against known viral hazards, such as rabies, yellow fever, smallpox, and poliomyelitis, and should receive prophylaxis against infectious hepatitis and malaria. Requesting access to immune serum to Lassa virus and possibly Marburg virus should be considered.

Field workers should be aware that there is a very serious risk when handling the rodent *Mastomys natalensis*, from which Lassa virus has been isolated, the fruit bat *Eidolon helvum*, and the shrew *Crocidura* sp., from which the rabies-related Lagos bat and Mokola viruses have been isolated. It is therefore recommended that these animals, and particularly their tissues and fluids, be handled with some care. Rubber gloves and respirators are recommended attire for handling these animals. In addition, ectoparasites on all animals should be immobilized or killed with chloroform or ether before the animals are manipulated for taxonomic or virological purposes.

Other viral diseases not previously mentioned that may be contracted during field work in West Africa are chikungunya, O'nyong nyong, dengue 1 and 2, Wesselsbron, West Nile, Zika, Bunyamwera group, shuni, Thogoto, Chandipura, Rift Valley, Tataguine, and Bangui.

The following West African viruses have caused infections in laboratory workers and should be handled with special precautions: Lassa, chikungunya, Semliki Forest, dengue 1 and 2, Wesselsbron, West Nile, yellow fever, Zika, Bwamba, Crimean haemorrhagic fever-Congo, Dugbe, Rift Valley, and Bhanja. Undoubtedly, others will be added to this list as more extensive work is done. Marburg virus is certainly a candidate for this list as it has recently been isolated in South Africa, far from the original source in East Africa.

Cryogenic containers and a dependable source of liquid nitrogen are necessary to maintain reliable low-temperature refrigeration of virological specimens, since this method is economical and efficient. Other methods of low-temperature refrigeration for virological specimens have so far proved impractical in West Africa. The active support of an interested vertebrate museum employing personnel capable of accurately identifying sampled animals is of paramount importance, particularly when taxonomic questions regarding the animals involved are in a state of flux and when great difficulty is encountered in field identification, particularly of juvenile animals.

RÉSUMÉ

VIRUS AUTRES QUE LES ARÉNAVIRUS CHEZ LES MAMMIFÈRES SAUVAGES D'AFRIQUE OCCIDENTALE. FACTEURS AFFECTANT LA TRANSMISSION DES VIRUS À L'HOMME ET AUX ANIMAUX DOMESTIQUES

Des recherches virologiques sérieuses ont débuté en Afrique occidentale avec la création de la Commission de la Fièvre jaune pour l'Afrique en 1925. La recherche de virus chez de petits mammifères d'Afrique occidentale a commencé en 1962 à l'Institut Pasteur de Dakar. En 1964, un Laboratoire de recherche sur les virus a été créé à Ibadan, Nigéria. Au cours des dix années suivantes, des milliers d'animaux sauvages ont été étudiés dans ces deux laboratoires et l'on a pu ainsi isoler au moins 37 virus différents. Certains de ces agents infectent l'homme et les animaux domestiques; beaucoup d'autres n'ont pas encore fait l'objet d'études assez poussées.

Il existe en Afrique occidentale au moins huit zones de végétation écologiquement distinctes, qui ont d'importants effets sur les populations d'animaux sauvages et leur répartition géographique. Dans la forêt tropicale humide on trouve un grand nombre d'espèces animales dont la population est faible mais stable. Dans les régions arides, les extrêmes de température, de pluviosité et d'humidité ont un effet opposé.

L'homme modifie rapidement l'habitat animal en Afrique occidentale. Les régions arides du nord subissent la pression des peuplements humains et des peuplements d'animaux domestiques. Le surpeuplement de ces régions par l'homme et les animaux a abouti à un surpâturage et à une destruction généralisée des herbages vivaces. Cette destruction de l'habitat animal a des effets profonds sur les peuplements animaux et crée un déséquilibre écologique. Les tribus nomades accompagnées de leurs bovins, moutons, chèvres et chameaux traversent de vastes étendues de l'Afrique occidentales, franchissent un grand nombre de zones écologiques, transportant des virus et des tiques vectrices et offrant ainsi des repas de sang à d'autres vecteurs.

Les populations d'Afrique occidentale se livrent pour la plupart à l'agriculture de subsistance et continuent d'avoir des contacts intimes avec les animaux sauvages dont elles recherchent la viande pour se nourrir. Les logements en Afrique occidentale sont fréquemment infestés par des animaux. Des chauves-souris logent souvent sous les toits de chaume et, dans certaines habitations de bambou recouvert de boue, les petits mammifères trouvent d'excellents abris. La cuisine est communément partagée entre plusieurs familles apparentées et l'on y stocke les aliments: racines, fruits, céréales, ce qui attire les petits mammifères. Dans les villes, les égouts sont à ciel ouvert, l'évacuation et l'élimination des déchets se fait mal et les produits alimentaires ne sont pas conservés en lieu sûr, de sorte que l'on voit se développer d'importants peuplements de petits mammifères.

Le virus de Lassa, isolé sur *Mastomys natalensis*, le virus de Mokola, de type rabique, que l'on rencontre chez la musaraigne (*Crocidura* sp.) et le virus de Dugbe que l'on trouve chez le rat géant (*Cricetomys gambianus*) sont responsables de certaines maladies constatées chez l'homme; les virus de Lassa et de Mokola sont parfois mortels. La fièvre hémorragique de Crimée et le virus du Congo que l'on rencontre au Nigéria chez le hérisson d'Afrique (*Atelerix albiventris*) ont provoqué de graves épidémies au Zaïre, en Ouganda et en URSS, mais la maladie n'a pas encore été constatée chez l'homme en Afrique occidentale. Un virus du type varioleux isolé chez une gerbille (*Tatera kempii*) en bonne santé au Dahomey pourrait être dangereux un jour pour l'homme en Afrique occidentale.

De nombreux facteurs influant sur les populations de petits mammifères en Afrique occidentale (dynamique, distribution, identification, différenciation des espèces, mélanges entre animaux, préférences des parasites et des vecteurs) auraient besoin d'être étudiés plus à fond. Il faudrait pour cela envoyer sur le terrain des équipes mobiles qui seraient vaccinées contre la rage, la fièvre jaune et la variole et qui devraient faire l'objet de mesures prophylactiques contre l'hépatite infectieuse et le paludisme. Il faudrait envisager aussi la possibilité de protéger les équipes mobiles par des immuns-sérums contre le virus de Lassa et le virus de Marburg.

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