THE ARBOVIRUSES: EPIDEMIOLOGY *and* ECOLOGY

Volume II

Thomas P. Monath

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The Arboviruses: Epidemiology and Ecology

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Editor

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FOREWORD

The term "arbovirus" is used to describe a diverse array of viruses which share a common feature, namely transmission by arthropod vectors. This ecological grouping now includes over 500 viruses, most belonging to five families — the Togaviridae, Flaviviridae, Bunyaviridae, Reoviridae, and Rhabdoviridae. Over 100 of these agents have been associated with naturally acquired disease in humans and/or domestic animals, and among these approximately 50 of the most important pathogenic viruses have been selected for detailed review under this title.

The complexity of arbovirus ecology requires a fundamental understanding of the influence of each of the multiple components (virus, vector, viremic host, clinical host, and environment) on infection and transmission cycles. The first volume, devoted to the variables which affect arbovirus transmission, provides this background and also contains guidelines for the design of future epidemiological investigations. Armed with these general principles, the student, teacher, or research worker will be able to structure specific knowledge about individual arbovirus infections found in Volumes II through V.

Recent textbooks are available which provide comprehensive coverage of the clinical aspects, pathogenesis, virological characteristics, and molecular biology of arboviruses. The intent of this book is different, for it focuses on the epidemiology and ecology of the arboviruses, the risk factors underlying the appearance of disease in the community, and the roles of arthropod vector and vertebrate hosts in virus transmission. Emphasis is placed on the field and laboratory evidence for involvement of vector and host species and on the ecological dynamics which determine their ability to spread infection. Elements of transmission cycles which are susceptible to surveillance, field investigation, prevention, and control are elucidated.

A number of arboviruses which have caused human disease only on rare occasions are not included in the book or are mentioned in passing within chapters on related diseases. Although these viruses (for example, Spondweni, Ilheus, Rio Bravo, Usutu, Orungo, Wanowrie) are inherently interesting and may, with changing ecologic conditions, turn out to be medically important, little or no information about their epidemiology (insofar as it relates to clinical hosts) is available. Finally, the scope of this book has been limited strictly to arthropod-borne infections and other viruses sometimes considered under the aegis of arbovirology (e.g., rodent-borne viral hemorrhagic fevers) are not included.

The compilation of a book of this scope required sacrifices in time and energy by a large number of contributors, all of whom faced multiple other commitments. This sacrifice will, I expect, be partially compensated by the availability of a useful compendium of collective knowledge.

Thomas P. Monath
October 1986

THE EDITOR

Thomas P. Monath is Director of the Division of Vector-Borne Viral Diseases, Centers for Disease Control, and is an affiliate faculty member of the Department of Microbiology, College of Veterinary Medicine, Colorado State University.

He received his undergraduate and M.D. degrees from Harvard University and his clinical training in Internal Medicine at the Peter Bent Brigham Hospital, Boston. In 1968 he joined the U.S. Public Health Service, serving as Medical Officer in the Arbovirology Unit, Centers for Disease Control, Atlanta, and later as Chief of the Arbovirus Section. Between 1970 and 1972, he was assigned to the Virus Research Laboratory of the Rockefeller Foundation, University of Ibadan, Nigeria, where he conducted field research on the epidemiology of yellow fever and Lassa fever. Since 1974, Dr. Monath has been Director of the Division of Vector-Borne Viral Diseases, Fort Collins, Colorado. In 1984 — 1985 he spent a sabbatical year in the Gastroenterology Unit of the Massachusetts General Hospital.

Dr. Monath is a Fellow of the American College of Physicians, the Infectious Disease Society, and the Royal Society of Tropical Medicine and Hygiene. He is a member of the American Society of Virologists, the American Society of Tropical Medicine and Hygiene, and the Association of Military Surgeons. He serves on the Editorial Boards of the *American Journal of Tropical Medicine and Hygiene, Acta Tropica,* and the *Journal of Virological Methods*. Dr. Monath is a member of the Committee on Research Grants, Board of Science and Technology for International Development, National Research Council, and is currently Chairman of the AIBS Infectious Diseases and Immunology Peer Review Panel to the U. S. Army Medical Research and Development Command. He is a member of the World Health Organization Expert Committee on Virus Diseases and the Pan American Health Organization Scientific Advisory Committee on Dengue, Yellow Fever, and *Aedes aegypti*. He has served as Chairman of the Executive Council of the American Committee on Arthropod-Borne Viruses, as a Councilor of the American Society of Tropical Medicine and Hygiene, and as a member of the Directory Board, International Comparative Virology Organization and the U. S.-Japan Cooperative Medical Research Program Panel on Virus Diseases.

Dr. Monath has authored or coauthored over 140 scientific publications in the field of virology and is editor of the book, *St. Louis Encephalitis,* published by the American Public Health Association. His main research interests are the ecology, epidemiology, and pathogenesis of arbovirus infections.

TO THE MEMORY OF MY PARENTS

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TABLE OF CONTENTS

Volume II

Chapter 14

AFRICAN HORSE SICKNESS

William R. Hess

TABLE OF CONTENTS

I. HISTORICAL BACKGROUND

A. Discovery of Agent and Vectors

In a report published in 1921, Theiler[1] stated that at least seven enzootics of African horse sickness (AHS) had occurred in the Cape Province during the period from 1780 to 1918. Prior to that time, there were no horses in South Africa, and the disease was not known there or elsewhere. The disease emerged only after horses from Europe and the East Indies were imported to South Africa. It was not immediately recognized as a separate disease entity. Because it had some clinical features similar to anthrax and piroplasmosis, it was often mistaken for those diseases. Various bacteria, parasites, and even a fungus were suggested as possible causative agents of AHS. However, in 1900, M'Fadyean[2] succeeded in transmitting the disease with a bacteria-free filtrate of blood from an infected horse. These findings were confirmed by others 1 year later,[3-5] and it was generally accepted that the causative agent was a virus.

When it was realized that the disease was not spread by mere contact, it was correctly assumed that the virus (AHSV) was probably transmitted by a blood-sucking arthropod.[6] The list of suspected vectors was enormous. Mechanical transmission by *Stomoxys calcitrans* was demonstrated.[7] However, its importance as a transmitter was discounted because it was a daytime feeder, and it was found that horses confined to mosquito-proof stables at night were protected against infection.[6] Because of their prevalence during an outbreak of AHS in the Sudan, *Lyperosia minuta* was regarded as a possible transmitter.[8] Other investigators suggested that certain ticks and several members of the order Diptera were likely vectors of the virus (AHSV).[9,10] Most of the claims were conjectural, and early efforts to test the vector capabilities of some of the suggested insects were negative. Nieschultz and co-workers[11,12] studied the mosquito fauna at Onderstepoort and, after numerous transmission attempts, concluded that mosquitoes were not the vectors of horse sickness.

Du Toit[13] recovered AHSV from field-trapped *Culicoides spp.* by injecting a horse with a suspension of the triturated flies. Later, he succeeded in transmitting ASHV by feeding *Culicoides* on an infected horse and 12 days later refeeding them on a susceptible horse.

Ozawa and Nakata[14,15] succeeded in experimentally transmitting AHS by feeding artificially infected mosquitoes on susceptible horses. Three species — *Anopheles stephensi*, *Culex pipiens*, and *Aedes aegypti* — proved to be potentially capable of acting as biological vectors of AHSV.

Later studies at Onderstepoort once again cast doubts upon the capability of mosquitoes and also *Culicoides* to act as biological vectors of AHSV.[16] Finally, Boorman et al.[17] demonstrated that *C. variipennis* could be infected by feeding on AHSV-infected embryonated hen eggs.[17] After 7 days, the infected midges were able to transmit the virus by bite to uninfected eggs, thus proving that *C. variipennis* could act as a true biological vector of AHSV in the laboratory. The fact that closely related bluetongue virus (BTV) was found to be transmitted by *Culicoides spp.* has apparently been taken as further evidence that AHSV is similarly transmitted. At any rate, AHSV is generally assumed to be a *Culicoides*-borne arbovirus.[18] This assumption and studies on the distribution and possible windborne dissemination of *Culicoides* have led to the suggestion that the spread of AHS over long distances has been the result of windborne transport of AHSV-infected midges.[19]

Although *Culicoides* transmission of AHSV in nature is not to be denied, the experimental demonstration of infection, replication, and transmission of AHSV by at least three species of mosquitoes should not be ignored.[14,15] Also, the possible role of ticks in the transmission of AHSV in certain areas is worthy of serious consideration. The isolation of AHSV from street dogs in the Aswan Province in Egypt,[20] and the subsequent demonstration that the dog tick, *Rhipicephalus sanguineus sanguineus,* is experimentally capable of transmitting the virus, are indicative of the possible involvement of a tick-dog cycle in the year-round maintenance of the virus in an area where the disease is enzootic.[21] In the same area, AHSV has been isolated from camels and the tick species that is regularly associated with them, *Hyalomma dromedarii.*[22] The virus replicates and can pass transstadially through the developmental stages of the tick. Transovarial transmission was not demonstrated, but starved infected adults readily fed on and transmitted the disease to horses.

B. History of Epizootics

A report of a devastating disease of horses which, in retrospect, was considered to be AHS appeared in records of the Cape Colony of South Africa in 1719. About 1700 horses imported by the Dutch East Indies Company were destroyed by the epizootic.[23] Thereafter, the disease recurred annually after the spring rains and continued until the first frost. Epizootics producing extensive losses occurred about every 20 years in the Cape Colony. The most damaging ones were in 1780, 1801, 1819, 1839, and 1854—1855. In the epizootic of 1854—1855, nearly 70,000 or more than 40% of the total horse population of the Cape of Good Hope died of the disease. In addition to the Cape, AHS proved to be enzootic in most of Africa south of the Sahara. Wherever horses, mules, or donkeys were introduced, AHS was sure to appear.[23]

Aside from its annual or seasonal occurrences in the enzootic regions of Africa, AHS has spread a number of times during this century far beyond its usual confines. In 1928, the disease spread slowly along the Nile Valley from Sudan into Egypt.[24] Although the number of animals involved was not large, about 89% of the horses and 70% of the mules that contracted the disease died. There were also some deaths among donkeys. The disease died out during the winter, and no outbreaks were reported in the region during the next 15 years. In the summer of 1943, AHS again appeared in Sudan and spread north to the Nile delta. It subsided during the winter, but unexpectedly recurred in Egypt in 1944 and then spread to Palestine, Syria, and Jordan. The losses were relatively small but portentous.[18] It was clearly evident that AHS was capable of spreading rapidly and extensively.

A major epizootic occurred in 1959—1960 with the disease appearing in Iran, West Pakistan, and Afghanistan in the summer of 1959. It reappeared in the spring of 1960 and rapidly spread to India, Turkey, Cyprus, Iraq, Syria, Lebanon, and Jordan. It was estimated that 300,000 *Equidae* were destroyed by the epizootic.[25]

The last widespread epizootic of AHS occurred during 1965—1966.[26] Algeria, Morocco, Tunisia, and Spain were affected. By this time, vaccines were available and control methods

were fairly well established. Animal losses were undoubtedly reduced substantially by the forceful application of control measures. Nevertheless, the epizootic was costly.

C. Social and Economic Impact

The horse has always occupied a somewhat unique position among domesticated animals. It may have tremendous sentimental as well as economic value, and in either case, its loss may be deeply felt. The histories of African exploration, conquest, and agricultural development were profoundly affected by AHS. Because the mortality rate among horses south of the Sahara was close to 90%, the early explorers rode oxen, followed navigable rivers, or walked; military expeditions were without mounted cavalry; and the early settlers often were obliged to use animals other than horses to till their fields. The disease is still a real threat to the livelihood of the small farmer who depends on the horse as a beast of burden. However, in the more developed countries, the horse is now kept almost entirely for recreational purposes. In some countries, it has actually increased in numbers, quality, and monetary value. With its high mortality rate and capability of rapid spread, AHS could still cause considerable losses before being brought under control.

II. THE VIRUS

A. Antigenic Relationships

AHSV is classified along with the viruses of BTV, Ibaraki disease, epizootic hemorrhagic disease of deer, and a number of other related viruses that have been isolated from insect vectors as an orbivirus, a genus within the family Reoviridae.[27] The orbiviruses are arboviruses that consist of ten segments of double-stranded RNA surrounded by a double-layer protein shell. They have large doughnut-shaped capsomeres and are ether resistant and acid labile. Although these viruses are structurally and biochemically very similar and have a common replication strategy, it is believed that the present nomenclature does not adequately point up the differences and the relationships among the members of the group.[28,29] For example, BTV and AHSV are almost indistinguishable by physicochemical means. Some hybridization between their nucleic acids has been demonstrated.[30] Both are transmitted mainly by *Culicoides;* however, their host ranges are different, and they are serologically distinct.

Over the years, marked differences in the efficacy of vaccines produced from different AHSV isolates were noted.[31] As a group, the AHSV isolates were identifiable by complement fixation (CF), but within the group, nine distinct serological types were identified by neutralization (N) tests. Recognition of the serotypes was particularly important for the fabrication of effective vaccines.[32,33]

B. Host Range

Natural infections with AHSV have been found in equines, dogs, and camels.[22,34] Among the equines, susceptibility is highest in horses, somewhat lower in mules, and lowest in donkeys. Mortality rates follow the same order, with rates as high as 95% for horses in some outbreaks and about 80% for mules. African donkeys are quite resistant to AHS, and few deaths have occurred among them. Mortality rates have varied considerably from one epizootic to another, but they have always followed the same general pattern. However, in the 1960 epizootic in the Middle East, substantial losses occurred among donkeys. The donkeys in that region are apparently more vulnerable than the African donkey.[18] Zebras are normally highly resistant, but some deaths from AHS have been reported.

The susceptibility of the dog to AHS was observed over the years by a number of investigators,[35-38] and it was generally believed that the disease could be acquired by the dog only by eating infected meat or by experimental injection of AHSV. In a search for

animals other than equines that might harbor the virus over the winter in Egypt, Salama and co-workers[20] examined 111 blood samples collected during the winter from street dogs in an enzootic area in Aswan Province. Isolations of AHSV were made from three of the samples, thus proving that some dogs, at least in that area, were naturally infected and carried the virus during the winter.[20] Two AHSV isolations were also made from camels in the Aswan Province of Egypt.

Also in the search of reservoir hosts in Africa, some sera of both wild and domesticated animals have been tested for the presence of AHSV-specific antibodies. Although the surveys were quite modest, significant antibody levels were found in elephants and zebra.[39-42] Virus was isolated from zebra, but not from elephants. In a survey of domesticated animals other than equines in Egypt, antibodies to AHSV were found in sheep (23.5%), goats (14%), dogs (7%), camels (5%), and buffalo (4%). Antibodies were not found in cattle. As stated previously, virus isolations have been made from dogs and camels in Egypt.[44] Judging from the antibody levels found in sheep and goats, they too may be naturally infected.

Experimental infections have been produced in a wide variety of animals. Some of the early workers claimed to have infected cattle and goats. Some of the observations must be regarded as suspect because they were apparently unable to distinguish between AHS and heartwater in cattle and goats.[34] It was found that white mice could be infected by intracerebral (i.c.) inoculation, and that virus serially passaged became neurotropic. With the exception of rabbits, most of the common laboratory animals (guinea pigs, hamsters, and rats) may be infected with the mouse-adapted neurotropic strains of AHSV.[44]

C. Strain Variation

The antigenic plurality of strains of AHSV was recognized by Theiler[45] as early as 1908. The degree of virulence, the nature of the disease produced, and the levels of immunity elicited were among the various strain differences noted. From a study of 84 virus strains on hand at the Onderstepoort laboratory, McIntosh[32] established the existence of 7 distinct immunological types of AHSV. A few years later, Howell[33] added two more serotypes to the array and speculated on the origin and stability of the various types. There are numerous strains in each serotype. Because some give rise to better immunizing agents than others, great care must be used in selecting strains for vaccine production. The task of selecting strains to be used as live vaccines was especially difficult. The so-called attenuation of virus by serial passage in mouse brains or cell cultures was laborious and time consuming. The task was lightened somewhat when it was found that there was a positive correlation between plaque size and pathogenicity in AHSV strains grown in cell cultures.[46] However, there is no correlation between plaque characteristics and immunogenicity. The expensive and time-consuming animal testing of clones of low virulence for immunogenicity is still required. So far, effective vaccine strains selected by these means have proved to be stable.

D. Methods for Assay

Isolation and titration of AHSV may be accomplished by i.c. inoculation of young mice.[44,47] In a typical virus isolation and titration, suckling mice are inoculated i.c. with 0.025 mℓ of a serial 10-fold dilution of the substance to be tested (blood, tissue suspension, triturated vectors, etc.). Five to ten mice are used per dilution. They are observed daily for 2 weeks for nervous signs and prostration. Deaths are recorded, and the virus LD_{50} dose is calculated. The brains of some mice *in extremis* are harvested for further passage and virus identification by CF or typing by N tests. Also, the virus may be typed by testing a precipitating antigen extracted from the infected mouse brains with reference sera of the nine AHSV serotypes in an Outcherlony gel diffusion test.

Cell culture methods are also being used in isolating, identifying, and titrating AHSV.[46,48,49] Roller tube cultures of baby hamster kidney cells (BHK21) are used for primary virus isolation

and titration, and virus typing may be done by a routine plaque N test on African green monkey kidney cells (VERO).[47]

III. DISEASE ASSOCIATIONS

A. Humans

Infections with AHSV have not been reported in man.

B. Domestic Animals

Aside from the horse, mule, and donkey, the dog is the only other domestic animal to display clinical signs and sometimes die of infection with AHSV. The disease in equines is of greatest concern; therefore, the brief descriptions of clinical features and pathology presented here will refer to the disease as it occurs in horses. Four forms of the disease have been distinguished:[50,51]

1. **The peracute or pulmonary form.** This form of AHS is usually seen in severe epizootics where the mortality rates are high. The incubation period is 3 to 5 days. There is an acute febrile reaction that may last only 1 or 2 days and reach 104 to 105°F. This is followed by progressive respiratory involvement usually including severe dyspnea and spasmotic coughing. The animal stands with its legs spread and its head extended. Its nostrils are dilated, and at the time of death, a frothy fluid may flow from them. The animal actually drowns in its own fluids. Death usually follows within a few hours after the first clinical signs appear. The mortality rate is over 90%. The most characteristic changes seen at necropsy are edema of the lungs and an effusion of serous fluid in the pleural cavity. The lymph nodes, especially those in the thoracic and abdominal cavities, are enlarged and edematous. Periaortic and peritracheal edematous infiltration, hyperemia of the glandular fundus of the stomach, congestion of the renal cortex, hyperemia and petechial hemorrhages in the mucosa and serosa of the large and small intestines, and subcapsular hemorrhages in the spleen are other changes often seen. Petechial hemorrhages occur in the pericardium, and the pericardial sac may contain fluid. Epi- and endocardial petechial hemorrhages are occasionally seen, but cardiac lesions are usually not outstanding. The disease in dogs is usually the pulmonary form.
2. **Cardiac or subacute edematous form.** This form of AHS is caused by virus strains of lower virulence, or it may occur in immune animals infected with heterologous strains of the virus. The incubation period is about 7 to 14 days, and the first clinical sign is a febrile reaction that lasts 3 to 6 days. As the fever begins to subside, characteristic edematous swellings develop. They first appear in the supraorbital fossae and eyelids and then extend to the lips, cheeks, and tongue. This subcutaneous edema may extend down the neck and involve the shoulders, the brisket, and the thorax. Before death, petechial hemorrhages appear in the conjunctivae and under the ventral surface of the tongue. Colic may precede death from cardiac failure. Death usually occurs within 4 to 8 days after the onset of fever. The mortality rate is about 50%. In animals that recover, the edema subsides in 3 to 8 days. Hydropericardium is the most prominent and constant change seen at necropsy. The pericardial sac may contain more than 2 ℓ of fluid. Usually there are petechiae and ecchymoses on the epicardium and endocardium. These hemorrhages are often most prominent along the course of the coronary vessels and beneath the bi- and tricuspid valves. The lungs may be normal or only slightly engorged. There is rarely an excess of fluid in the thoracic cavity. The gastrointestinal tract usually has lesions similar to those that occur in the pulmonary form of the disease. However, submucosal edema is usually much greater.

3. **Mixed form.** This is essentially a combination of the cardiac and pulmonary forms of the disease. The majority of fatal cases of AHS may be classified as the mixed form with lesions of either the pulmonary or cardiac form predominating.
4. **African horse sickness fever.** In its mildest form, AHS may appear as no more than a thermal response of 1 to 5 days duration. The temperature may go as high as 105°F, but usually after 2 days, the fever subsides and the animal recovers. This is the form of AHS which almost always occurs in goats or donkeys that are experimentally infected. In nature, this form of the disease might escape detection.

The fatal disease in dogs has usually been the pulmonary form.

C. Wildlife

It was clearly evident that the causative agent of AHS was present in South Africa before horses were introduced. The disease did not occur outside the continent of Africa, and it appeared only when horses were taken into certain areas of Africa. Therefore, a reservoir for the disease agent was sought among the indigenous animals. The zebra was a prime suspect, and some observers reported deaths among them that they attributed to AHS.[6] However, it was found that the disease was also contracted in areas where zebra and other game animals did not exist, and the injection of blood from small mammals, birds, reptiles, or amphibians into susceptible horses failed to produce the disease.[6] Much later, AHSV N and CF antibodies were found to be quite common in the blood of zebra and elephants in Kenya and South Africa.[39,41,42] Clinically recognizable AHS has been seen in zebra, and virus has been isolated. The presence of antibodies in the elephant has not been explained. Clinical disease has never been observed in elephants, nor has virus ever been isolated from them. A wildlife reservoir for AHSV has not been definitely established.

D. Diagnostic Procedures

In an area where the disease is enzootic, it may often be diagnosed in the field with a fair degree of accuracy. The clinical signs and gross lesions are usually characteristic enough to enable a presumptive diagnosis to be made. For example, edema of the supraorbital fossae is pathognomonic for the cardiac form of the disease.

However, some of the clinical signs and post-mortem findings of AHS may appear in other equine diseases such as equine infectious anemia, equine piroplasmosis, purpura hemorrhagica, and rhinopneumonitis. A confirmed diagnosis requires isolation and identification of the virus. This has usually been achieved by i.c. inoculation of unweaned mice with defibrinated blood taken at the peak of fever. Spleen suspensions (10%) have also been used. A litter of eight to ten mice is used. Each mouse is given 0.025 mℓ of blood diluted 1/10 in sterile distilled water or phosphate-buffered saline. They are observed for 2 weeks, and the brains of those that show nervous signs and prostration are removed and subpassed i.c. as a 10% suspension to another litter of suckling mice. After three to five serial passages, mortality is usually 100%. Viruses isolated in this manner are neurotropic and may no longer produce clinical disease in horses, although they are still antigenic. They have been especially valuable in the diagnosis of AHS. Antigens for CF test,[31] Outcherlony agar gel precipitin test (AGD),[43] and virus neutralization (N) test[44] have been prepared from brains of moribund mice. Stocks of type-specific reference viruses have also been prepared in mice, and they have been used to hyperimmunize rabbits to obtain type-specific antisera. Using these procedures, reagents, and tests, it is possible to isolate, identify, and type AHS viruses. It is also possible to survey animal populations for AHS antibodies. The CF test has been used for rapid diagnosis. It is group specific, but CF antibodies are rather short lived. For typing, the N test must be used. N antibodies are present for a much longer time.

In efforts to improve upon and possibly supplant the slow and tedious procedures of propagating AHSV by i.c. inoculation of unweaned mice, the use of cell cultures was introduced.[48,49,52] The methods were first applied to propagate and attenuate virus strains that had been isolated and typed by the established mouse brain methods. It was soon found that the viruses could be typed by N in cell cultures.[49] Finally, it was found that cell cultures could be used to isolate virus directly from naturally infected animals.[46] Of the numerous cell cultures tested, the stable monkey kidney cell lines MS and VERO and the baby hamster kidney cell line BHK21 proved to be most useful. Coexistence of virus and antibody in the blood of the infected animal has apparently accounted for some of the difficulty in isolating the virus. However, most of the virus in the blood appears to be firmly associated with erythrocytes, and these may be washed comparatively free of antibody. Virus isolation is facilitated by using an inoculum of washed erythrocytes hemolyzed by sonication or the addition of distilled water. The use of roller tube cultures also appears to favor virus isolation.[47]

Fluorescent antibody techniques have also been applied to AHSV detection. Although the methods are only group specific, they are more convenient and rapid than CF. Indirect immunofluorescence has been used successfully in an antibody survey in wild zebra in Kenya.[40]

A number of new tests are being developed, and promising preliminary trials have been conducted with some of them, but much more testing is required before they are likely to be accepted as standard procedures. Among them are microadaptations of the CF and AGD tests, hemagglutination tests with erythrocytes coupled with type-specific AHS antibodies used to type virus isolates, and an indirect enzyme-linked immunosorbent assay (ELISA).[53]

E. Effects of Virus on Vectors

Although some of the transmission studies with mosquitoes, *Culicoides,* and ticks have been quite detailed and quantitative with respect to size of blood meal, multiplication, and persistence of the virus in the vector, no mention has been made of adverse effects of the virus on the vectors.

IV. EPIDEMIOLOGY

A. Geographic Distribution

As its name implies, AHS apparently originated in Africa and at the present time appears to be confined to that continent. As stated previously, there were substantial incursions of the disease in the Middle East in 1944, Afghanistan, West Pakistan, Turkey, Iraq, India, and Cyprus in 1959 to 1961, and Spain in 1966. It was last reported in Pakistan in 1974 and Saudi Arabia in 1975.[54] Clinical AHS was reported in Yemen in 1980 and 1981, but may have been present as early as 1976.

Until 1930, the enzootic areas in Africa were south of the Sahara, mainly in South, East, and Central Africa. In 1930, the disease extended up the Nile Valley into Egypt and has occurred periodically in Southern Egypt ever since.

B. Incidence

No major epizootics of AHS have occurred since 1966. However, cases occur sporadically in the enzootic areas of Africa. In fact, there are 10 to 12 countries that have reported cases almost every year for the past 10 years or more.[54] Although the number of cases reported during the past several years is relatively small, the potential for the occurrence of a major epizootic is still present. The virus need only reach a country where there is a large susceptible or unvaccinated horse population. A capable vector is almost certain to be present.