BACTERIOLOGICAL REVIEWS, Sept. 1971, p. 310-364
Vol. 35, No. 3

Comparative Virology of Primates[1]

S. S. KALTER AND R. L. HEBERLING

Division of Microbiology and Infectious Diseases, Southwest Foundation for Research and Education, P. O. Box 28147, San Antonio, Texas 78228

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INTRODUCTION

Numerous species of monkeys and apes are currently employed for various experimental purposes. The exact number of animals involved is difficult to assess, but approximately 100,000 are imported annually into the United States. Undoubtedly an equal number are used by different laboratories outside the United States. Goodwin (107) notes that 951 projects involving simians were listed by The Science Information Exchange of the Smithsonian Institution for fiscal year 1967 at a cost of approximately $55,000,000. Augmented usage of various monkeys and apes may be anticipated for the future, as evidenced by the yearly increase in numbers employed in an attempt to comply with requests by laboratories and by development of additional major primate research centers throughout the world. Breeding programs are anticipated to limit the numbers of animals eventually imported, but such efforts will

[1] WHO Collaborating Laboratory on Comparative Medicine: Simian Viruses.

probably not result in a significant decrease in importation for some time to come, nor will this eliminate virological problems inherent to these animals.

Several reasons are usually given by investigators for experimental utilization of the nonhuman primate in deference to other laboratory animals. Perhaps most pertinent is the phylogenetic relationship of these animals to man. Admittedly there are investigators who find that the use of monkeys and apes invokes a certain glamor to their research, but, more frequently, usage is based upon the realization that data obtained from experimentation on nonhuman primates may be more appropriately collated to experimental findings with man. Impetus was given this concept after the failure to note the full congenital malforming capabilities of thalidomide when tested in the usual laboratory animals. However, before this event, investigators for many years resorted to the use of simians in attempts to find models for studies of human disease generally not satisfied by another animal system.

The observations of Enders and Peebles (73) and Rustigian et al. (286) on the presence of indigenous viruses in kidney cells of monkeys was followed by other investigations (91, 124–126, 138, 147, 149, 152, 154, 159–161, 167, 172, 174, 175, 177–179, 186, 187, 190, 192, 194, 195, 223, 224) which quickly emphasized that monkeys and apes must not be considered simply as "test tubes" (a role they still play in many laboratories) but as biological entities harboring a multitude of microbial and parasitic forms. In many instances these organisms are similar to those of man, but many also are distinct and common only to species under examination.

This report is a comparative virological evaluation of the different monkeys and apes currently employed in research primarily as a result of data selected by serological methods. Two points should be emphasized at the onset: (i) No attempt has been made to comprehensively review the entire nonhuman primate literature as it is too voluminous to be reported here in toto. (ii) In the early literature, reference frequently is not made to the genus and species of animal used, or it is incorrectly stated. Several comprehensive reviews concerned with viruses of monkeys and apes are available (147, 148, 156, 172, 177–179, 186).

HISTORICAL RESUME

Large-scale employment of nonhuman primates in the virus laboratory stems from the finding by Enders and his collaborators (74, 280) that monkey kidney cells are susceptible to poliovirus infection. Tissue culture (or cell culture) was not an original concept of these workers but was well established and, in fact, previously used in virology (155). Most noteworthy, however, was the practical demonstration by Enders et al. (74) of this technique for routine use in the laboratory. Before this disclosure, the susceptibility of simians to a variety of viruses was demonstrated in a number of limited experiments. Relatively large numbers of monkeys and apes were involved in other biological experimentation, especially behavioral studies. It is well known that various nonhuman primates were frequently used by early anatomists, as human dissection was generally prohibited.

One of the earliest recorded virus studies involving nonhuman primates was that of Pasteur et al. (262, 263) who demonstrated in 1884 that rabies virus would lose its virulence for dogs by passage through monkeys. Halberstaedter and von Prowazek demonstrated in 1907 the suceptibility of apes to trachoma (119). [The psittacosis-lymphogranuloma (Bedsoniae) group of agents are not considered to be true viruses. Their inclusion here is primarily for historical purposes.] Thomas (336) that same year suggested that yellow fever infection of the chimpanzee may serve as a reservoir for this disease. Shortly thereafter, in 1909, Landsteiner and Popper described the susceptibilities of *Macaca mulatta* and *Papio hamadryas* to poliomyelitis (215), a finding verified the following year by the studies of Flexner and Lewis (86) and again confirmed in 1912 by Kraus and Kantor (214) and Thomsen (337).

The virus etiology of measles was described in a series of reports by Anderson and Goldberger and Goldberger and Anderson (6–8, 105) with experimental reproduction of the disease in monkeys as well as transmission to other monkeys. These findings were supported by the studies of Nicolle and Conseil (256) and Lucas and Prizer in 1912 (220) and again, in greater detail, by Nicolle and Conseil (257) in 1920 and by Blake and Trask in 1921 (31, 32). Gordan (108) in 1914 was able to demonstrate that mumps was due to a filterable virus by monkey inoculation. Rivers (278) recovered the virus of varicella by inoculating monkey testes with vesicular fluid from patients with this disease (279). Similar studies with varicella virus were performed on several of the higher apes—orangutan, chimpanzee, and gorilla—during 1933–1934 by Eckstein (70). Contradictory results were reported by Cole and Kuttner (54) who failed to produce chickenpox in both rhesus and vervet monkeys with the use of human material.

In agreement with the hypothesis of Thomas (336) regarding a yellow fever reservoir in chimpanzees, Balfour (21) reported that natives in

Trinidad in 1914 were aware of a developing yellow fever wave because of the increased number of dead howler (*Alouatta palliata*) monkeys. The Rio de Janeiro yellow fever epidemic in 1928 introduced the sylvatic concept of yellow fever and clearly demonstrated the role that monkeys played in the epidemiology of this disease (326). Attempts to develop a yellow fever vaccine followed the demonstration by Hindle in 1929 (136) that monkey livers maintained their virulence for about 3 months after infection. Other arboviruses were similarly studied during this period. Simmons and collaborators (312, 313) examined Old World monkeys for their susceptibility to dengue. Louping ill was studied in monkeys by Hurst (164) and by Elford and Galloway (72). Rift Valley fever virus was shown capable of infecting monkeys by a number of different inoculation routes (83). Muckenfuss et al. (251) demonstrated the viral etiology of St. Louis encephalitis (SLE) by producing the disease in monkeys. The virus of lymphocytic choriomeningitis (LCM) was recovered from monkeys as a result of studies with SLE (12). Independently both Armstrong et al. (13) and Lillie (219) used monkeys for their experimental studies with LCM virus.

Blaxall (33), in 1923, suggested that the monkey was the most susceptible animal for studies on variola virus, a finding supported by the investigations of Bleyer (34), Gordon (109), and Teissier et al. (332). The occurrence of "natural" smallpox in an orangutan (*Pongo pygmaeus*) at the Djakarta Zoo was reported by Bras (40).

The marmoset (*Callithrix* sp.) was found by Teissier et al. (331) to be susceptible to herpes simplex virus with development of cutaneous disease. Hurst (165) described pseudorabies infections in the rhesus monkey. The occurrence of nuclear inclusions in the salivary glands of cebus (*C. fatuellus*) monkeys, now recognized as cytomegalovirus infection, was reported by Cowdry and Scott (56). Also of historical significance was the report by Sabin and Wright in 1934 (289) on the development of a fatal encephalitis in man bitten by a "normal" rhesus monkey.

Johnson and Goodpasture (166) reported that mumps virus was still infectious for man after several passages in monkeys. Bloch (35) found that clinical disease similar to that seen in man could be simulated in monkeys with mumps virus. The common cold was produced in anthropoid apes by means of a filterable agent (66). Findlay and Mackenzie (84, 85) state that fowl plague virus caused only a mild disease in monkeys.

Rabies as a natural infection of monkeys is apparently quite rare. However, the experimental susceptibility of a number of species—*M. sinicus*, *M. cynomolgus*, *M. callithrix*, *Cercocebus fuliginosus*, *P. mormon*, and *Troglodytes niger* (terms at variance with genus and species currently in use)—to rabies infection was demonstrated by Levaditi et al. in 1926 (217).

The chimpanzee was extensively used in the early 1940's (142–146) as an animal model in attempts to unravel the pathogenesis of poliomyelitis. Prior to these studies, however, a number of investigators had demonstrated the susceptibilities of various species of simians to the polioviruses. For example, Aycock and Kagan (18) in 1927 and Kling et al. (206, 207) in 1929 demonstrated that monkeys may be actively immunized against poliomyelitis by the repeated intracutaneous inoculation of live virus. Amoss (3) noted the similarity between experimental poliomyelitis produced in monkeys and the human disease. An outbreak of this disease in zoo animals was described by Goldman in 1935 (105). Neutralizing antibody to poliovirus was perceived by Aycock and Kramer (19) in monkeys after infection. The ability of normal rhesus and cebus monkey sera to neutralize poliovirus was reported by Jungeblut and Engle (170). Paul and Trask (265) observed an abortive form of poliomyelitis in monkeys. The occurrence of vascular lesions in monkeys after feeding poliovirus was discerned by a number of investigators (43, 206, 216, 290, 346). South American monkeys were found to be resistant to poliomyelitis (111, 222).

Adaptation of the Lansing strain (type 2) poliovirus to cotton rats (*Sigmodon hispidus hispidus*) was accomplished by Armstrong (11) only after serial passage through monkeys. An attempt to develop a poliomyelitis vaccine was related by Kolmer (208) and Kolmer and Rule (209) with the use of an inactivated infected monkey spinal cord in monkeys. Differences in susceptibility to poliovirus between rhesus and cynomolgus monkeys, the latter being susceptible by the oral route, were noted by a number of investigators (17, 42, 80). Trask and Paul (338) found the African green monkey to be susceptible to poliovirus.

Chimpanzees were described as highly susceptible to poliovirus infection, closely resembling man in their host reaction. Howe and Bodian (143) reported that bilateral section of the olfactory tract of the chimpanzee did not alter their susceptibility to oral infection with poliovirus. These investigators also demonstrated the portals of entry for poliovirus in the chimpanzee (142), penetration of the gastrointestinal tract (144), accidental infection (145), and failure of hyperimmune serum to protect against infection (146). Rhesus monkeys could be infected as evidenced

by the experiments of Aisenberg and Grubb (1), who produced paralytic poliomyelitis by instillation of infectious materials into the pulp canal of the animals' teeth. A mouse "poliomyelitis," i.e., encephalomyelitis virus of mice, was found to be nonpathogenic for monkeys by Theiler and Gard (334, 335). Encephalomyocarditis in apes was shown to be due to a filterable virus by Helwig and Schmidt (131).

Continued interest in the use of monkeys for the study of arboviruses was evidenced by the investigations of Shortt et al. (307). These investigators demonstrated mild phlebotomus fever in monkeys after inoculation with patient blood. Cultivated virus produced an inapparent infection. Monkeys from nonendemic areas may be induced to develop a very mild form of dengue (312). In Africa, West Nile virus produced an encephalitis in monkeys (319). Smithburn and Haddow (318) isolated a virus in the Semliki forests which caused a fatal encephalitis upon inoculation into monkeys. Haddow et al. (117) in 1947 discussed the relationship of baboons to yellow fever. Yellow fever vaccines were also evaluated in nonhuman primates. Fox et al. (87, 88) indicated that the more neurovirulent strains of 17D used in the yellow fever vaccine produced more encephalitis as assayed in monkeys. This was also true for the French neurotropic strain of yellow fever vaccine (Yellow Fever Vaccination, WHO Monograph no. 30, Geneva, 1956). Chimpanzees were susceptible to phelebotomus fever as well as dengue according to Paul et al. (264).

Rake and Shaffer (275) demonstrated that measles virus carried through 20 embryonate egg passages was still capable of producing illness in monkeys. Transmission of measles to monkeys with patients' blood was shown by Shaffer et al. (298). The disease, however, was milder than that seen in children. Mumps virus could be successfully transmitted to a number of different *Macaca*—*M. mulatta*, *M. irus*, *M. nemestrinus*, and *M. maurus*—by direct inoculation of the parotid gland by way of Stensen's duct (327).

These animal studies were a natural prelude to the cell culture studies initiated by Enders and his collaborators (74, 280). These culture systems provided the virus laboratory with a technical capability heretofore not possible. New viruses were isolated from man and other animals in an unparalleled number (124, 138, 159–161, 224, 225). In addition to numerous isolates recovered by inoculation of various cell cultures with body fluids and excreta, it soon became apparent that cultures of "normal" tissues also were not devoid of organisms. Two reports appeared almost simultaneously suggesting the existence of latent infections due to viruses in human adenoidal tissues (134, 282). This unmasking of viruses was shortly thereafter confirmed by the aforementioned finding of Enders and Peebles (73) and Rustigian et al. (286) and the existence of latent infections in simian tissues. The thousands of monkeys, primarily macaques, involved in poliovirus, measles and adenovirus studies, were found to contain indigenous agents which were isolated from excreta and tissues or cultures of tissues (77, 124, 138, 150, 154, 156–161, 167, 172, 174, 175, 177–179, 186–188, 194, 195, 199, 204, 273, 281, 284, 285, 320–322).

A series of reports, primarily as a result of the efforts of Hull and his collaborators in the United States (159, 160, 161) and Malherbe et al. (224, 225) in South Africa, provided a listing of simian viruses now recognized as possessing the same biological characteristics of other accepted groups of animal viruses. The characteristics and grouping of the majority of these agents have been the subject of several reviews (147, 148, 156, 172, 177–179, 186). Other agents, still not completely studied, reside in freezers in many laboratories. For example, at least 10 new simian serotypes, primarily adeno-, entero-, and herpesviruses, are currently under investigation in this laboratory (187). Rogers et al. (281) recently reported the isolation of new viruses from the chimpanzee. Others include those recently reported, also from the chimpanzee, by Soike et al. (320, 321, 322) and those found in New World monkeys as a result of a series of studies by Melendez and his collaborators (237–241).

NONHUMAN PRIMATES CURRENTLY UNDER STUDY IN VIROLOGY

Macaques were the animal of choice for much of the early virological investigations as a result of their employment for kidney cell cultures and ease of procurement. Dissatisfaction with this animal because of fear of *H. simiae* and presence of numerous indigenous viruses, as well as the need for other species in order to expand the spectrum of susceptible tissues and animals, has resulted in employment of over 30 different genera (Table 1). Limitations of the numbers involved, generally because of costs or their actual availability, has eliminated or minimized the use of certain species. A number of different species are no longer available because their numbers have been decimated and they are now included among the endangered animals. It is unfortunate that current practices of trapping and handling of many of these animals have not taken appropriate conservation measures into consideration. Furthermore, only too frequently, a particular monkey or ape is chosen because that species is available, rather than because it is more

TABLE 1. *Genus and species of monkeys and apes currently used in virus research*

Genus and species[a]	Common name
Old World	
Gorilla (*G. gorilla*)	Gorilla
Pan (*P. troglodytes*)	Chimpanzee
Pan (*P. paniscus*)	Chimpanzee (pigmy)
Pongo (*P. pygmaeus*)	Orangutan
Hylobates (*H. lar*)	Gibbon
Papio spp. (*P. cynocephalus*, group: *P. anubis*, *P. papio*, *P. ursinus*-Chacma)	Baboon
Papio (*P. hamadryas*)	Baboon (Hamadryas)
Theropithecus (*T. gelada*)	Baboon (Gelada)
Cercopithecus (*C. aethiops*)[b]	Grivet (*Aethiops* group; other groups: *Mono*, *Nicititans*, etc.),
Cercopithecus (*C. sabaeus*)[b]	Green
Cercopithecus (*C. pygerythrus*)[b]	Vervet
Cercopithecus (*C. talapoin*)	Talapoin
Presbytis (*P. entellus*, *P. cristatus*)	Langur
Erythrocebus (*E. patas patas*)	Patas
Macaca (*M. mulatta*)	Rhesus
Macaca (*M. fascicularis*)[c]	Cynomolgus
Macaca (*M. radiata*)	Bonnet
Macaca (*M. nemestrina*)	Pigtailed macaque
Macaca (*M. cyclopis*)	Formosan rock
Macaca (*M. speciosa*)	Stumptail
Macaca (*M. fuscata*)	Japanese macaque
New World	
Saimiri (*S. sciureus*)	Squirrel
Aotus (*A. trivirgatus*)	Owl
Alouatta (*A. belzebul*)	Howler
Ateles (*A. paniscus*)	Spider
Cebus (*C. capucinus*)	Capuchin
Lagothrix (*L. lagothricha*)	Woolly
Pithecia (*P. pithecia*)	Sakis
Callithrix	Marmosets
Cebuella (*C. pygmaea*)	Pigmy
Saguinus (*S. tamarin*)	Tarmarin
Leontideus (*L. rosalia*)	Golden lion tamarin

[a] Only major species are included herein; a number of other genera and species are used by various authors. The following are derived from J. R. Napier and P. H. Napier, *A Handbook of Living Primates*, 1967.

[b] Considerable confusion regarding which of these species is used in the laboratory. See Napier and Napier for complete listing and description.

[c] Currently preferred species name for *M. irus*, *M. cynomolgus*, and *M. philippinensis*.

useful. In this vein, considerable thought must be given to the choice of animal employed in an experiment. The simplest animal system should always be considered, and then, if it does not satisfy the experimental need, thought could be given to a "higher" animal. Here, too, if a rhesus monkey or a vervet will serve satisfactorily, there is no need to use a chimpanzee.

Simians employed in the laboratory fall into two major groups: Old World and New World monkeys and apes. Old World monkeys are further subdivided into Asian and African animals. These geographic divisions were originally for convenience but now are recognized as having the possible advantage of indicating a difference in species susceptibility as well as the serendipitous effect of suggesting the origin of the virus. In this respect, the SV designation was originally used by Hull (161) for viruses isolated from the Asian macaques. The SA nomenclature was used by Malherbe (223) for viruses he isolated from cercopithecoids. As will be emphasized below, this distinction has been confused unfortunately by the practice of intermingling species after their capture. Thus, in many instances the true origin of many simian viruses is questionable or has been misdirected. Differences in species susceptilities to viruses are now well recognized. Geographic differences are also recognized but need more study. Many ecological factors are undoubtedly involved in the distribution of certain viruses, but they have not been clearly defined.

CAPTURE, SHIPPING, AND HANDLING OF NONHUMAN PRIMATES: EFFECT ON THE VIRAL FLORA

It is recognized that all the nonhuman primates, as well as other animals, have a viral flora indigenous for that species. Crossing of species barriers occurs, but to what extent this happens in nature is not known. In addition, numerous antigenically closely related organisms, recognized in different animals, may give rise to misinterpretation of data. The origin of various viruses encountered in an animal's tissues or excreta is often clouded by the lack of study on these animals in their natural habitat and environment. Field studies on the various nonhuman primates currently in use in the laboratory have been extremely limited. The rhesus monkey has been examined by several groups (28, 247, 301, 302, 344) immediately after capture. Our laboratory maintains a field station in Kenya, and a number of studies have been completed on the baboon at the time of capture (175, 176, 194, 195). Most information that is available has resulted from investigating animals of varying and unknown histories under conditions that generally compound the problem. Compromising the obscure background of most animals is the failure of investigators to take into account the amount of contact the animal under study has had with other animals, including man, prior to capture. It is well known that many of the monkeys and apes now in the laboratory have come from areas where they have lived in close proximity to man, often sharing the same food and water source as well as deposition of body wastes.

Cognizance of actual practices employed in the trapping, capture, and subsequent handling of

nonhuman primates will enable investigators to recognize the source of certain of the animal's viral flora. Practices currently employed do much to promote ill health and death in large numbers of animals. This affects not only the cost but, perhaps more importantly, the future supply of these animals. Improvements have been attempted but still fall short of good conservation.

Capture

The mechanics of actually trapping monkeys is relatively simple; it is complicated by the human element. For example, higher apes are more difficult to capture and, as a result, the adults are frequently sacrificed to obtain the young.

In trapping monkeys, various devices are employed, from nets of different sizes to capture boxes of dissimilar designs. Other than the traumatic psychological experience for the animal at the time of capture, probably very little is changed virologically at that moment. However, the devices used for trapping purposes rarely have been cleaned or even sterilized. If nets are employed, excreta are distributed all over the animals. This serves to dispense various organisms not previously disseminated as a result of herd contact. Cage trapping has the advantage of maintaining animals individually or in small groups but fails to take into account that these cages require thorough cleaning after every trapping experience. Furthermore, even when animals are trapped singly, this individuality is often destroyed by trappers who maintain these animals in gang cages until shipment is made.

Trappers, in addition to their own operations, are not adverse to increasing their supply of animals by purchasing available monkeys from natives. Natives who collect animals for sale generally live under very primitive conditions. The animals are kept tied or caged in the homes until a purchaser passes by. Obviously the association of man, his domestic animals, and the monkey is very intimate, and exchange of viral flora easily and readily occurs.

Holding in Exporting Country

Little improvement over field conditions may be expected at these holding facilities. The personnel employed, as well as the operator, have little knowledge of proper hygienic measures necessary to minimize the exchange of organisms between man and animals in their keeping. In fact, because of this deficiency, these holding areas enhance the spread of microorganisms rather than decrease it. Caretakers, cages, and food and water supply as well as the containers are generally maintained under very unhygienic conditions. Public health measures are not known—or worse, are frequently ignored. Finally, the opportunity for exposure to new simian contacts, of the same and different species, exposes the monkey to possible infection by simian viruses in the same way that military recruits and school children acquire a variety of virus infections.

Shipping

An attempt has been made by the various airlines to develop better methods for holding the animals in their care at the shipping stage. Again, for various reasons (usually fiscal), species are often intermingled in the carriers or at the interchanges and stopovers, which usually have inadequate facilities for the proper care of the animals. Recommendations have been made to improve actual caging, but additional improvements are urgently needed.

Holding in Importing Country

Some attempts have been made to improve the quality of care given animals upon arrival in the various importing countries. The same problem exists here, in that little in-depth cognizance is given to sanitation. Inadequate basic knowledge, as well as the lack of training regarding proper procedures in individuals involved in handling the animals, results in the spread of organisms. Frequently the problem of organism interchange is compounded in the importers' holding areas as different species from all over the world are now brought together. This extensive mixing of species by the importers, although not intended at times, results from either lack of knowledge regarding the problem or indifference. In most instances, however, further intermingling occurs in the laboratory facility, where different species are brought together or fresh flora are introduced into stabilized animals.

Few laboratories have the capability for direct involvement in the capture of animals they employ; other laboratories have initiated breeding programs to supply the required animals. Both methods unquestionably will provide a higher grade animal. However, failure to properly maintain such animals will negate these efforts. Very limited information is available as regards gnotobiotic nonhuman primates.

MATERIALS AND METHODS

Little special methodology has evolved as a result of studies on comparative virology of nonhuman primates. Procedures employed are those associated with virus laboratories involved in animal virology, with some modifications adapted to the immediate situation, primarily in the employment of homologous tissues. Accordingly,

procedures employed for the study of simian viruses are those used primarily by both human and veterinary laboratories.

Most data on the virological background of monkeys and apes were obtained from serological or isolation studies (or both). Sera were tested in various laboratories for the presence or absence of antibody to viruses of human and simian (occasionally with viruses of other animals) origin. Isolation procedures have included attempts to recover viruses from various body fluids, tissues, or excreta of the test animals. Methods employed in our laboratory have been described in detail (173); those of other laboratories may be found in the original articles.

Serology

Standard testing adapted to micro-procedures (295) includes complement fixation (CF), hemagglutination inhibition (HI), and serum neutralization (SN). More recently immunodiffusion and immunofluorescence tests have been used for detection of antigen as well as antibodies to the Australia antigen (36) and other viruses. Possible existence of nonspecific reactions associated with the CF and HI tests prompted greater attention to use of neutralization tests in our laboratory. All results in our laboratory, in addition to repeated testing, were carefully evaluated in terms of the control systems. Any evidence of "nonspecific" reactions prompted exclusion of that serum from the series. Serum elimination may be noted by examining the tables and finding differences in the number of sera used in one test as compared with another. A micro-neutralization procedure suitable for use with most viral systems has been recently reported (130) and is now also standard in our laboratory.

In a number of instances several groups of sera have been tested on animals from a single laboratory. These may have represented multiple bleedings on the same animals or could have been entirely different groups of animals.

Isolation

Procedures for the recovery of viruses from nonhuman primates have been well described (124, 138, 161, 223). These methods have obviously been generally acceptable, as evidenced by the abundance of agents now recognized. Approximately 70 simian virus prototypes recovered from rhesus, cynomolgus, baboon, African green, patas, squirrel, marmoset, and chimpanzee specimens have been described (Table 2). Latent infections also have been reported as a result of long-term cultivation of simian tissues (National Cancer Institute, Monograph no. 29, 1968). As suggested above, greater success in isolation of viruses may be obtained by using tissues from the same animal species under study. Many viruses demonstrate a strong predilection for certain cell culture, others will grow on a variety of cell systems. Usually several different cell cultures are employed for best results. Also, one must consider the availability of certain monkeys and apes for tissue donors, e.g., gorilla, orangutan, etc. Only limited studies on gnotobiotic animals have been done, without any evidence of viruses recorded.

Viruses

A few laboratories have used virus types other than the recognized simian virus serotype viruses employed by us and other investigators. Human viruses also have been used for comparative purposes. Few comparative studies involving viruses of nonprimates or their tissues have been included.

In many instances, the antigens employed (Table 3) were crude preparations of infected cell cultures, some of which were obtained through commercial sources (Lederle Laboratories, Markham Laboratories, Microbiological Associates, Inc., Flow Laboratories) or various government agencies (e.g., Center for Disease Control; Research Reference Reagents Branch, National Institutes of Health). Lacking these, antigens in our laboratory were prepared from prototype strains derived from the Simian Virus Reference Center, World Health Organization Laboratory on Comparative Medicine: Simian Viruses collection maintained at our Foundation; or from strains obtained from the American Type Culture Collection, Rockville, Md. Procedures employed have been described by the original investigator or published in detail and are standard for this laboratory (173).

SEROLOGICAL EVIDENCE FOR INFECTION WITH HUMAN AND SIMIAN VIRUSES

A number of reports are available describing and defining the viral flora of nonhuman primates (147, 148, 156–158, 177–179, 181, 183, 186, 188, 190, 192, 197–199). These reports are concerned primarily with characterizing and classifying more than 70 isolates recovered from various tissues, excreta, and body fluids of monkeys and apes now employed in the laboratory. Hull (156), in an excellent review, summarized the pertinent literature regarding the physical and biological properties of these viruses. This section will review the serological evidence for infection of

primates with these simian viruses as well as with other viruses primarily of human origin (Tables 4–17). Findings with human sera (Table 4) are provided as a source of comparison.

TABLE 2. *Biological characteristics, original host source, and grouping of simian viruses*

Simian adenoviruses (DNA,[a] ether resistant, 70–80 nm, acid stable, nuclear inclusions, HA±)
- SV1, 11, 15, 17, 20, 23, 25, 30, 31, 32, 33, 34, 36, 37, 38-rhesus, cynomolgus
- SA7, 17, 18-African green
- V340, AA153-baboon
- C-1, PAN 5, 6, 7-chimpanzee
- Sq M-1-squirrel monkey

Simian picornaviruses (RNA,[b] ether resistant, 18–38 nm, acid stable, cytoplasmic inclusions, HA±, $MgCl_2$ stabilized)
- Enteroviruses
  - SV2, 6, 16, 18, 19, 26, 35, 42, 43, 44, 45, 46, 47, 49-rhesus, cynomolgus
  - SA5-African green
  - A13-baboon
- Unclassified picornaviruses
  - SV28-rhesus
  - SA4-African green

Simian reoviruses (RNA, ether resistant, 70–77 nm, acid stable, cytoplasmic inclusions, HA+, $MgCl_2$ stabilized)
- SV12 (Reo 1), SV59 (Reo 2)-rhesus
- SA3 (Reo 1)-African green

Simian papovaviruses (DNA, ether resistant, 40–57 nm, acid stable, nuclear inclusions, HA−)
- SV40-rhesus
- SA12 (?)-African green

Simian herpesviruses (DNA, ether sensitive, 120–250 nm, acid labile, nuclear inclusions, HA−)
- Type A
  - *H. simiae* (B virus)-rhesus
  - SA8-African green
  - *H. tamarinus* (*platyrrhinae*)-squirrel
  - SMV-spider
- Type B
  - SA6-African green
  - *Herpes saimiri* (?)-squirrel
  - Liverpool vervet agent (?)-African green, patas

Simian poxviruses (DNA, ether or chloroform sensitive, 200–325 nm, acid labile, cytoplasmic inclusions, HA±)
- Vaccinia-Variola group
  - Monkey pox-cynomolgus
- *Moluscum contagiosium* group (?)
  - Yaba-rhesus
  - Yaba-like disease (benign epidermal pox, 1121)-rhesus

Simian myxoviruses (RNA, ether sensitive, 150–250 nm, acid labile, cytoplasmic, and nuclear inclusions, HA+)
- SV5-rhesus (man?)
- SV41-cynomolgus
- SA10-African green

TABLE 2—(*Continued*)

Foamy virus[c] (RNA (?), ether sensitive, 100–300 nm, acid labile, no inclusions, HA−)
- Type 1 rhesus, African green
- Type 2 African green
- Type 3 African green
- Type 4 squirrel
- Type 5 galago
- Type 6 chimpanzee
- Type 7 chimpanzee

Miscellaneous viruses
- SA11-African green
- SHF-rhesus
- Marburg agent-African green

[a] DNA, deoxyribonucleic acid.
[b] RNA, ribonucleic acid.
[c] Presently included with myxoviruses (myxo-like viruses).

Adenoviruses

Serological determination of infection with the adenoviruses may be routinely performed by the usual laboratory procedures. As all adenoviruses, with the exception of avian strains, presumably cross-react in the CF test, this procedure may be used first to detect previous infection by an adenovirus and then another, more specific procedure (HI, SN, etc.), employed for determination of the specific type. Sera negative in the CF test, however, may still be positive when tested by another method. Group CF antibody has been detected in all species of primates examined thus far.

Determination of adenovirus antibody in newly captured simians has been limited to a few species: a small group of chimpanzees (184), baboons (175–179, 181, 183, 188, 197, 199), rhesus, and small numbers of a variety of other monkeys (*E. patas, C. aethiops tantalus, C. mona, C. nictitans, Mandrillus leucophaeus, C. erythrogaster, Cercocebus torquatus, M. radiata, P. entellus;* see references 28, 301, 302). Sera from chimpanzees in the wild have not been tested to the same extent as other nonhuman primates. Adenovirus group antibody was, however, frequently detected by the CF test. A small number of these newly captured animals also had SN antibody to SA7 and human adenovirus type 12 (Table 6), both types known to produce tumors in hamsters inoculated at birth. Baboon sera from animals immediately after capture rarely were found with this CF group antibody. However, when these same sera were assayed in the HI or SN tests, they were observed to have antibody to various individual adenoviruses, especially those (SA7, V340) originally recovered from African simians (Table 8). Antibody to SV23 was not found in serum from any newly trapped baboon.

TABLE 3. *Virus antigens employed for serological surveys*

Virus group	Human	Simian
Adenovirus	Adeno group antigen	SV1, 15, 23
	Ad12, tumor antigen	SA7, tumor antigen
	AAV1-4	V340
Arbovirus	Western encephalitis	
	Eastern encephalitis	
	St. Louis encephalitis	
	Colorado tick	
	Yellow fever	
Herpesvirus	*H. hominis*	*H. simiae*, *H. tamarinus*, SA8
Myxovirus	Inf. A, A_1, A_2, B	SV5, 41
	Measles (rubeola)	
	Mumps	Foamy virus 1-3
	Parainfluenza 1-3	
	Respiratory syncytial	
Papovavirus	-	SV40
Picornavirus	Polio 1-3	SV4, 16, 19, 45, 49, A13
	Coxsackievirus A9, A20	
	B1-6	
	Echo 1, 3, 4, 6, 7, 9, 11, 12, 13	
Poxvirus	Vaccinia	Monkey pox
Reovirus	1-3	SV12, 59
Miscellaneous	Rubella	Marburg virus
	Lymphocytic choriomeningitis	Simian hemorrhagic fever

SN antibody to SV32 and SV33 were reported by Bhatt et al. (28) to be rather frequent in bonnet sera and to a somewhat lesser extent in rhesus and langur sera. Only one of the 47 rhesus sera were discovered to have HI antibody to human adenovirus type 2 of types 1 to 7 tested. Shah and Morrison (301) found that 38% of the free-living rhesus in North India had antibody to SV20 and 12% were detected with antibody to SA7. The presence of antibody to this latter virus, which was derived from an African green monkey (*C. aethiops*), makes one speculate regarding the origin and contact of these animals with other simians. Shah and Morrison (301) attribute these positive reactions to a low order of heterotypic response to related viruses.

Captive animals reflect a broader antibody response than free living primates, presumably as a

TABLE 4. *Antibody to human and simian viruses in human sera*[a]

Antigen	Serology test	Source of sera			
		Kenya	SFRE	Laboratory no. 11	Recruits[b]
Adenovirus					
Group antigen	CF	16/25[c]	27/63	6/10	17/25
Ad12	SN	5/35	2/23	-[d]	-
Ad12 (tumor)	CF	0/29	1/60	0/10	0/22
SV1	SN	0/18	0/23	-	-
SV15	SN	2/14	1/25	-	-
SV23	SN	1/34	-	-	-
SA7	SN	13/25	21/44	-	-
SA7 (tumor)	CF	0/29	0/60	0/10	0/22
V340	SN	9/34	12/22	-	-
Arbovirus					
EE	CF	0/32	0/63	0/10	0/25
WE	CF	0/32	0/63	0/10	0/25
SLE	CF	1/32	0/63	0/10	0/25
Colorado tick	CF	-	-	0/10	-
Yellow fever		-	-	-	-
Herpesvirus					
H. hominis	CF	0/32	3/61	6/10	7/25
H. simiae		-	-	-	-
H. tamarinus		-	-	-	-
SA8		-	-	-	-
Myxovirus					
Influenza A (PR8)	CF	19/24	25/62	4/10	15/25
Influenza A (PR8)	HI	1/24	30/40	8/10	4/24
Influenza A_1 (FM1)	HI	5/24	31/40	10/10	18/24
Influenza A_2 (Jap)	HI	3/24	38/40	10/10	22/24
Influenza B (Lee)	CF	11/24	9/62	1/10	12/25
Influenza B (Lee)	HI	3/24	17/40	8/10	5/42
Measles (rubeola)	CF	0/29	6/60	0/10	0/23
Measles (rubeola)	HI	14/30	34/42	8/8	8/25
Mumps	CF	4/32	0/60	2/10	3/25
Mumps	HI	11/28	12/47	10/10	12/25
Parainfluenza 1	CF	0/25	0/63	0/10	0/25
Parainfluenza 1	HI	8/26	16/43	7/10	10/24
Parainfluenza 2	CF	1/25	2/63	4/10	4/25
Parainfluenza 2	HI	1/26	17/43	5/10	4/24
Parainfluenza 3	CF	9/25	1/63	5/10	13/25
Parainfluenza 3	HI	5/26	18/43	4/10	6/24
Respiratory syncytial	CF	0/25	0/63	0/10	3/25
SV5	HI	1/25	-	5/10	3/20
SV41	HI	0/25	-	0/10	0/21
Foamy 1		-	-	-	-
Foamy 2		-	-	-	-
Foamy 3	SN	1/21	1/20	-	-
Papovavirus					
SV40	SN	0/36	14/72	-	-

TABLE 4—*Continued*

Antigen	Serology test	Source of sera			
		Kenya	SFRE	Laboratory no. 11	Recruits[b]
Picornavirus					
Polio 1	SN	17/34	16/22	–	–
Polio 2	SN	32/35	21/23	–	–
Polio 3	SN	23/35	8/9	–	–
Cox. A9	SN	15/33	14/22	–	–
Cox. A20	HI	0/27	0/58	1/10	0/25
Cox. B1	SN	9/33	7/22	–	–
Cox. B2	SN	18/35	9/20	–	–
Cox. B3	SN	19/33	8/22	–	–
Cox. B4	SN	12/14	9/21	–	–
Cox. B5	SN	1/16	2/22	–	–
Cox. B6	SN	4/14	4/21	–	–
Echo 1	SN	12/35	2/22	–	–
Echo 3	HI	10/27	24/58	1/10	0/25
Echo 6	SN	7/11	4/19	–	–
Echo 7	HI	10/34	22/57	1/8	8/25
Echo 9	SN	5/10	3/18	–	–
Echo 11	HI	7/27	12/50	1/10	0/25
Echo 12	HI	10/33	36/53	0/8	1/25
Echo 13	HI	3/27	11/58	1/10	0/25
SV4	SN	1/34	0/22	–	–
SV16	HI	1/26	6/56	0/10	0/25
SV19	SN	0/44	5/23	–	–
SV45	HI	0/30	0/42	0/10	0/25
SV49	SN	3/28	5/23	–	–
A13	SN	0/10	0/23	–	–
Poxvirus					
Vaccinia	HI	3/23	5/52	2/9	3/25
Monkey pox	HI	13/24	8/57	2/9	8/25
Reovirus					
Reovirus 1	HI	16/33	44/63	0/10	6/25
Reovirus 2	HI	16/33	45/63	2/10	6/25
Reovirus 3	HI	3/18	30/55	8/10	11/25
SV12	HI	15/25	11/56	2/10	4/25
SV59	HI	15/33	46/60	–	–
Miscellaneous					
Rubella	HI	–	54/54	8/9	25/25
Lymphocytic choriomeningitis	CF	2/32	1/60	0/10	0/25
Marburg[e]	CF	0/29	0/49	0/9	–
Simian hemorrhagic fever	CF	0/28	0/57	0/10	–

[a] Abbreviations: CF, complement fixation; SN, serum neutralization; HI, hemagglutination inhibition; EE, Eastern encephalitis; WE, Western encephalitis; SLE, St. Louis encephalitis; Cox., coxsackievirus; LCM, lymphocytic choriomeningitis virus; SHF, simian hemorrhagic fever.

[b] Army recruits, San Antonio, Tex.

[c] Number of sera positive/number of sera tested.

[d] Not done (–).

[e] A study on patient material is described in the text.

result of more recent and frequent contact with each other and with other animal species, including man. Antibody to several of the adenoviruses, both human and simian are found in human sera (Table 4). A single gorilla serum tested against the group antigen, human adenovirus type 12 (Ad12), SV1, SV15, SV23, and

TABLE 5. *Antibody to human and simian viruses in gorilla sera (laboratory 1)*[a]

Antigen	Serology test	Year of serum collection		
		1966	1967	1968
Adenovirus				
Group antigen	CF	0/14[b]	–[c]	0/14
Ad12		–	–	–
Ad12 (tumor)	CF	0/14	0/14	–
SV1		–	–	–
SV15	SN	–	0/11	–
SV23	SN	–	0/11	–
SA7		–	–	–
SA7 (tumor)	CF	0/14	0/14	–
V340	SN	–	0/11	–
Arbovirus				
EE	CF	0/14	0/14	0/14
WE	CF	0/14	0/14	0/14
SLE	CF	0/14	0/14	0/14
Colorado tick	CF	0/14	0/12	0/14
Yellow fever		–	–	–
Herpesvirus				
H. hominis	CF	0/14	0/14	0/14
H. simiae		–	–	–
H. tamarinus		–	–	–
SA8		–	–	–
Myxovirus				
Influenza A (PR8)	CF	0/14	0/14	0/14
Influenza A (PR8)	HI	0/3	0/9	0/14
Influenza A_1 (FM1)	HI	0/3	0/9	2/14
Influenza A_2 (Jap)	HI	1/3	1/9	10/14
Influenza B (Lee)	CF	0/14	0/14	1/14
Influenza B (Lee)	HI	0/3	0/9	2/14
Measles (rubeola)	HI	1/14	0/13	1/14
Mumps	HI	0/14	1/13	14/14
Parainfluenza 1	CF	0/14	0/14	0/14
Parainfluenza 1	HI	0/6	0/11	0/14
Parainfluenza 2	CF	0/14	0/14	0/14
Parainfluenza 2	HI	0/6	0/11	0/14
Parainfluenza 3	CF	0/14	0/14	0/14
Parainfluenza 3	HI	0/6	3/11	9/14
Respiratory syncytial	CF	0/14	0/14	0/13
SV5	HI	–	2/11	2/11
SV41	HI	–	0/11	0/11
Foamy 1		–	–	–
Foamy 2		–	–	–
Foamy 3	SN	–	0/1	–
Papovavirus				
SV40	SN	0/10	–	–
Piconavirus				
Polio 1	SN	–	10/11	–
Polio 2	SN	–	9/11	–
Polio 3	SN	–	8/11	–
Cox. A9	SN	–	2/11	–
Cox. A20	HI	0/14	4/13	0/14
Cox. B1	SN	–	0/10	–
Cox. B2	SN	–	0/11	–
Cox. B3	SN	–	0/11	–
Cox. B4	SN	–	0/11	–

TABLE 5—*Continued*

Antigen	Serology test	Year of serum collection		
		1966	1967	1968
Cox. B5	SN	–	0/11	–
Cox. B6	SN	–	0/11	–
Echo 1	SN	–	0/11	–
Echo 3	HI	0/14	0/13	3/14
Echo 4	CF	0/14	–	–
Echo 6	SN	–	1/11	–
Echo 7	HI	1/14	2/13	8/14
Echo 9	SN	–	0/11	–
Echo 11	HI	0/14	0/13	0/14
Echo 12	HI	0/14	1/13	0/14
Echo 13	HI	0/14	0/13	0/14
SV4		–	–	–
SV16	HI	1/14	0/10	–
SV45	HI	0/14	0/13	0/14
SV49		–	–	–
A13		–	–	–
Poxvirus				
Vaccinia	HI	0/12	0/13	0/14
Monkey pox	HI	0/11	0/13	0/14
Reovirus				
Reovirus 1	HI	6/14	5/13	3/14
Reovirus 2	HI	5/14	6/13	3/14
Reovirus 3	HI	11/14	6/11	2/14
SV12	HI	6/14	2/10	–
SV59	HI	5/14	–	–
Miscellaneous				
Rubella	HI	8/9	10/12	13/14
Lymphocytic choriomeningitis	CF	0/14	0/14	0/14
Marburg		–	–	–
Simian hemorrhagic fever		–	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Number of sera positive/number of sera tested.
[c] Not done (–).

V340 was originally found positive only to the Ad12 virus (197). A larger series of gorilla sera were found to be generally devoid of adenovirus antibody when tested with the group CF antigen (198). More recent studies on sera collected after several years in captivity (*unpublished data*) indicate antibody in these animals to SV15, SV23, AA153, and V340 (Table 5). Adenovirus antibody is very prevalent in chimpanzee sera. As reported previously (184, 197) and as presented in Table 6, chimpanzee sera from various laboratory colonies were found with antibody to the CF group antigen, Ad12, SV1, SV15, SV23, V340, and SA7. Additional testing, recently completed, also showed antibody to SV33, SA18, AA153, and Pan7 in addition to those listed previously. Marked differences were noted in the number of animals that were positive at the different laboratories. Also, more chimpanzee sera were found to be seropositive with African viruses than with Asian viruses. Orangutan and gibbon sera were usually free of adenovirus antibody (Table 7), although antibody to the group antigen was found in a number of orangutan sera and 2 of the 26 gibbon sera examined previously (197). More recently, 5 of 22 orangutans were found with antibody to SV23 and 1 of 22 sera was positive to SV33. In preparing rhesus monkey antisera to human enteroviruses, Kamitsuka et al. (201) found that these sera cross-reacted with a number of simian adenoviruses: SV1, SV15, SV17, SV20 (?), SV23, SV25, SV27, SV30, SV31, SV32, SV33 (?), SV34, SV36, SV37, and SV38. The results did not indicate antigenic relationships but rather the presence of antibody to these viruses as a result of previous infections.

Captive monkeys, like the greater apes, also appear to maintain a consistently higher prevalence of antibody to the viruses of their geographic origin, although it is not as marked as in newly captured animals. Captivity undoubtedly is a major factor in the redistribution of many of these viruses. For example, SV23 has been found on only several occasions in a newly captured African animal. Less information is available on New World monkeys and adenovirus antibody. We have examined several different species (marmoset, howler, spider, capuchin) without any evidence of antibody (with possible exception of one marmoset) to the CF group antigen, SA7 or V340 (197). Deinhardt et al. (61) also were unable to find CF adenovirus antibody in sera on newly received marmosets nor after 1 year in captivity.

In an interesting comparative study, Shah and Morrison (301) examined sera from rhesus monkeys "free-living" in North India, "free-ranging" on Cayo Santiago and in the San Juan, Puerto Rico, laboratory colony. All three groups were reported to have antibody to SA7 and SV20, although the prevalence of SA7 antibody was considerably lower in the free-living group than was antibody to SV20. Pedreira et al. (266) did not find antibody to human type 4 virus by both CF and SN tests, and Heath and his collaborators (123) were unable to detect HI or SN antibody to SV17 in African green monkeys.

Rapoza and Atchinson (276) examined sera derived from rhesus, grivet, vervet, and patas monkeys for adenovirus group-specific antibody and AAV-1 antibody. All sera except those from the patas monkeys had the group antibody, but only the rhesus sera had AAV-1 antibody. Similar studies were reported by Mayor and Ito

TABLE 6. *Antibody to human and simian viruses in chimpanzee sera*[a]

Antigen	Serology test	Source of sera										
		Laboratory (Lab) no. 1					Lab 2	Lab 4	Lab 7	Lab 15	SFRE	
		1963	1966	Lab born	1967	1968					Pre[b]	Post[b]
Adenovirus												
Group antigen	CF	20/32[c]	32/34	21/29	28/69	12/35	29/36	29/40	18/24	1/6	8/16	14/15
Ad12	SN	–[d]	–	–	0/26	–	9/23	3/11	–	–	–	–
Ad12 (tumor)	CF	0/23	0/44	–	0/69	–	1/20	0/30	0/22	0/4	2/14	2/16
SV1	SN	3/51	–	–	–	–	1/24	2/11	–	–	–	4/17
SV15	SN	6/52	–	–	0/25	10/24	0/11	9/25	–	–	–	2/18
SV23	SN	2/52	–	3/20	–	–	0/20	–	–	–	–	0/18
SA7	SN	16/54	–	–	11/21	–	1/6	12/23	–	–	1/4	3/17
SA7 (tumor)	CF	0/23	0/44	0/26	0/69	–	0/20	0/30	0/22	0/4	–	2/16
V340	SN	7/51	–	–	9/22	–	0/8	3/11	–	–	–	5/17
Arbovirus												
EE	CF	0/26	0/44	0/29	0/69	0/36	0/42	0/24	0/24	0/1	0/7	0/14
WE	CF	2/26	0/44	0/29	0/69	1/36	0/42	0/40	0/24	0/1	0/17	0/14
SLE	CF	0/21	0/44	0/29	0/69	0/24	0/40	0/41	0/24	0/1	0/17	0/16
Colorado tick	CF	0/19	0/10	0/26	0/69	0/24	0/46	0/25	–	–	0/13	0/16
Yellow fever		–	–	–	–	–	–	–	–	–	–	–
Herpesvirus												
H. hominis	CF	1/26	0/43	0/28	0/69	0/27	0/41	2/38	0/24	0/1	0/15	4/14
H. simiae		–	–	–	–	–	–	–	–	–	–	–
H. tamarinus		–	–	–	–	–	–	–	–	–	–	–
SA8		–	–	–	–	–	–	–	–	–	–	–
Myxovirus												
Influenza A (PR8)	CF	0/17	0/44	0/29	0/68	3/33	0/31	1/37	0/21	1/4	0/12	0/12
Influenza A (PR8)	HI	2/31	0/27	0/25	0/62	0/35	1/53	2/36	0/24	0/7	0/13	0/16
Influenza A_1 (FM1)	HI	0/31	0/27	0/25	0/62	1/35	2/53	2/36	0/24	0/7	0/13	0/16
Influenza A_2 (Jap)	HI	1/31	1/27	0/25	3/62	26/35	33/54	8/36	0/24	7/7	0/13	1/16
Influenza B (Lee)	CF	1/17	0/44	0/29	0/68	2/33	0/31	0/37	0/24	0/4	0/12	0/12
Influenza B (Lee)	HI	0/31	0/27	0/25	0/62	0/35	6/53	2/36	0/24	0/7	0/13	0/16
Measles (rubeola)	CF	0/23	0/44	0/16	0/69	—	0/20	0/51	0/23	–	0/16	0/16
Measles (rubeola)	HI	11/43	6/42	5/28	0/69	6/36	9/41	9/40	0/24	6/6	0/17	0/16
Mumps	CF	1/26	2/44	0/29	0/69	3/36	1/40	6/41	1/24	0/1	0/17	0/16
Mumps	HI	0/13	2/36	2/27	4/64	17/23	5/46	26/41	1/24	5/7	0/17	0/16
Parainfluenza 1	CF	0/27	0/44	0/29	0/69	0/35	0/17	0/40	0/24	0/6	0/16	0/15
Parainfluenza 1	HI	1/13	0/27	1/25	3/66	1/24	0/46	6/36	0/21	1/7	0/13	0/16
Parainfluenza 2	CF	3/27	0/44	0/29	0/69	0/33	0/47	2/40	0/24	0/6	0/16	0/15
Parainfluenza 2	HI	0/13	0/27	0/25	1/66	1/24	1/46	4/36	0/21	1/7	0/13	0/16
Parainfluenza 3	CF	10/27	0/44	0/29	0/69	0/33	1/47	20/40	8/24	0/6	0/16	3/15
Parainfluenza 3	HI	6/13	11/27	4/25	3/66	19/24	6/46	19/40	6/21	4/7	0/13	3/16
Respiratory syncytial	CF	20/27	4/44	4/29	8/69	1/32	0/47	8/40	0/24	4/6	11/16	0/5
SV5	SN	13/49	–	–	–	–	12/39	0/11	–	–	–	–
SV41	SN	4/52	–	–	–	–	3/40	0/11	–	–	–	–
Foamy 1	SN	–	–	–	–	–	0/9	–	–	–	–	–
Foamy 2	SN	–	–	–	–	–	0/10	–	–		–	–
Foamy 3	SN	3/28	–	–	–	–	–	0/1	–	–	–	–
Papovavirus												
SV40	SN	0/51	–	–	0/17	–	0/24	0/22	2/25	–	–	0/18

TABLE 6—*Continued*

Antigen	Serology test	Source of sera										
		Laboratory (Lab) no. 1					Lab 2	Lab 4	Lab 7	Lab 15	SFRE	
		1963	1966	Lab born	1967	1968					Pre[b]	Post[b]
Picornavirus												
Polio 1	SN	4/52	–	–	14/25	–	1/24	0/11	1/25	–	–	4/18
Polio 2	SN	16/52	–	–	10/25	–	7/21	8/11	23/25	–	–	3/18
Polio 3	SN	9/25	–	–	13/25	–	5/24	4/11	0/20	–	–	3/18
Cox. A9	SN	7/52	–	–	6/22	–	4/23	1/9	–	–	–	4/18
Cox. A20	HI	0/16	0/38	0/29	38/64	0/31	2/50	0/38	0/22	0/7	0/17	4/15
Cox. B1	SN	0/52	–	–	14/25	–	1/24	0/11	–	–	–	0/18
Cox. B2	SN	3/52	–	–	1/21	–	1/24	1/11	–	–	–	0/18
Cox. B3	SN	0/52	–	–	1/21	–	0/22	1/10	–	–	–	0/18
Cox. B4	SN	0/52	–	–	0/19	–	0/19	0/9	–	–	–	1/17
Cox. B5	SN	2/52	–	–	0/20	–	1/19	0/9	–	–	–	0/17
Cox. B6	SN	3/50	–	–	0/21	–	0/15	0/9	–	–	–	1/17
Echo 1	SN	1/51	–	–	0/21	–	1/24	2/11	–	–	–	0/17
Echo 3	HI	2/16	27/38	12/29	29/65	5/31	20/50	5/38	8/22	7/7	11/17	7/16
Echo 4	CF	0/19	–	–	0/24	–	0/28	–	–	–	0/13	0/16
Echo 6	SN	10/20	–	–	6/25	–	1/4	–	12/25	–	–	4/18
Echo 7	HI	0/25	7/30	25/27	27/65	9/36	36/51	10/40	10/24	0/6	13/17	10/16
Echo 9	SN	3/35	–	–	1/22	–	0/9	–	0/25	–	–	2/18
Echo 11	HI	2/16	9/38	3/29	23/65	1/31	5/50	2/38	2/22	6/7	11/17	1/15
Echo 12	HI	12/56	8/41	22/27	13/65	0/36	1/51	1/40	0/24	0/6	3/17	1/16
Echo 13	HI	0/16	4/38	1/29	10/65	0/31	0/50	0/38	1/22	0/7	1/17	3/15
SV4	SN	0/51	–	–	–	–	0/23	2/11	–	–	–	–
SV16	HI	0/13	0/24	1/26	0/62	–	1/23	3/41	1/24	1/1	3/17	2/15
SV19	SN	8/51	–	–	–	–	8/22	4/11	–	–	–	–
SV45	HI	3/28	0/38	0/27	0/69	0/21	0/49	1/40	0/24	1/6	0/17	0/18
SV49	SN	9/52	–	–	–	–	2/24	3/11	–	–	–	–
A13	SN	0/52	–	–	–	–	8/18	1/11	–	–	–	–
Poxvirus												
Vaccinia	HI	0/8	0/41	0/23	0/60	0/24	0/34	1/40	–	1/7	0/14	2/16
Monkey pox	HI	–	2/21	0/14	9/69	0/24	7/34	6/41	2/24	1/7	4/14	3/13
Reovirus												
Reovirus 1	HI	6/17	28/41	26/27	35/65	10/31	24/51	19/40	8/24	1/1	5/17	2/16
Reovirus 2	HI	7/17	34/41	26/27	45/65	8/31	6/51	8/40	8/24	1/1	3/17	1/16
Reovirus 3	HI	5/20	6/30	25/27	32/55	6/20	7/50	28/41	15/24	1/2	15/17	10/15
SV12	HI	2/13	19/24	19/26	29/62	–	8/23	32/41	12/24	1/1	15/17	3/15
SV59	HI	7/17	33/41	26/27	–	–	4/23	–	–	–	–	–
Miscellaneous												
Rubella	HI	0/8	15/32	1/14	28/47	10/23	5/32	15/32	3/21	1/4	4/12	14/14
Lymphocytic choriomeningitis	CF	0/21	1/44	0/29	0/69	0/36	3/40	1/40	0/23	0/7	0/17	0/16
Marburg	CF	0/21	1/34	0/27	–	–	15/32	0/30	–	0/1	2/15	–
Simian hemorrhagic fever	CF	–	–	–	0/69	–	–	0/23	–	–	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Pre, collected immediately after capture; Post, approximately 6 to 9 months in captivity.
[c] Number of sera positive/number of sera tested.
[d] Not done (–).

(233) on African green and rhesus monkey sera for antibody to SV15 and AAV-4. These investigators indicated that 3 of 14 green monkey and 2 of 2 rhesus monkey sera had antibody to SV15. All but one green monkey was reported as having AAV-4 antibody. Captive rhesus monkeys, but not those in the wild, were noted to have antibody to AAV-1, -2, and -3, according to

TABLE 7. *Antibody to human and simian viruses in orangutan and gibbon sera*[a]

Antigen	Serology test	Orangutan (laboratory no. 1)				Gibbon		
		1963	1966	1967	1968	Laboratory no. 1	Laboratory no. 4	Laboratory no. 7
Adenovirus								
Group antigen	CF	5/10[b]	8/28	1/28	1/19	2/9	0/8	0/9
Ad12	SN	0/23	–[c]	–	–	0/4	–	–
Ad12 (tumor)	CF	0/22	0/25	0/28	–	0/6	0/4	–
SV1	SN	0/22	–	–	–	–	–	–
SV15	SN	0/36	–	–	–	–	–	–
SV23	SN	1/21	–	–	–	0/6	–	–
SA7	SN	0/19	–	–	–	–	–	–
SA7 (tumor)	CF	0/22	0/25	0/28	–	0/6	0/4	–
V340	SN	0/21	–	–	–	0/6	–	–
Arbovirus								
EE	CF	0/18	0/28	0/28	0/21	0/9	0/8	0/9
WE	CF	0/18	0/28	0/28	0/21	0/9	0/8	0/9
SLE	CF	0/24	0/28	0/28	0/33	0/8	0/8	0/9
Colorado tick	CF	0/20	0/23	0/28	0/34	0/5	0/8	–
Yellow fever		–	–	–	–	–	–	–
Herpesvirus								
H. hominis	CF	0/18	0/28	0/28	1/20	0/9	0/8	0/9
H. simiae		–	–	–	–	–	–	–
H. tamarinus		–	–	–	–	–	–	–
SA8		–	–	–	–	–	–	–
Myxovirus								
Influenza A (PR8)	CF	0/23	0/28	0/28	0/18	0/5	0/8	0/9
Influenza A (PR8)	HI	4/22	0/17	0/25	1/21	2/9	0/8	–
Influenza A_1 (FM1)	HI	4/22	0/17	0/25	2/21	3/9	0/8	–
Influenza A_2 (Jap)	HI	10/22	6/17	2/25	17/21	3/9	0/8	–
Influenza B (Lee)	CF	0/23	0/28	0/28	0/18	0/5	0/8	0/5
Influenza B (Lee)	HI	4/22	0/17	0/25	1/21	2/9	0/8	–
Measles (rubeola)	CF	0/22	0/25	0/28	–	0/6	0/8	0/9
Measles (rubeola)	HI	4/23	3/28	0/28	1/21	3/9	1/8	0/9
Mumps	CF	0/18	0/28	0/28	0/21	0/9	0/8	0/9
Mumps	HI	0/19	0/26	0/27	23/33	0/4	0/7	–
Parainfluenza 1	CF	0/6	0/28	0/28	0/21	0/9	0/8	0/9
Parainfluenza 1	HI	0/17	0/20	0/24	0/34	0/4	0/8	–
Parainfluenza 2	CF	1/6	0/28	0/28	0/20	0/9	0/8	0/9
Parainfluenza 2	HI	0/17	0/20	0/24	0/34	0/4	0/8	–
Parainfluenza 3	CF	0/6	0/28	0/28	0/21	0/9	0/8	3/9
Parainfluenza 3	HI	0/7	0/20	4/24	12/34	0/4	0/8	–
Respiratory syncytial	CF	0/6	0/28	1/28	3/21	0/9	0/8	0/9
SV5	HI	–	0/7	13/23	3/29	1/4	–	–
SV41	HI	–	2/7	2/23	0/29	0/5	–	–
Foamy 1		–	–	–	–	–	–	–
Foamy 2		–	–	–	–	–	–	–
Foamy 3	SN	5/19	–	–	–	–	–	–
SV40	SN	0/38	–	–	–	0/7	–	0/9
Picornavirus								
Polio 1	SN	0/22	–	–	–	0/7	–	–
Polio 2	SN	0/22	–	–	–	0/7	–	–
Polio 3	SN	1/22	–	–	–	0/1	–	–
Cox. A9	SN	0/22	–	–	–	0/3	–	–
Cox. A20	HI	0/17	0/21	7/23	0/22	0/8	0/7	0/9
Cox. B1	SN	0/22	–	–	–	–	–	–

TABLE 7—*Continued*

Antigen	Serology test	Orangutan (laboratory no. 1)				Gibbon		
		1963	1966	1967	1968	Laboratory no. 1	Laboratory no. 4	Laboratory no. 7
Cox. B2	SN	2/22	–	–	–	–	–	–
Cox. B3	SN	0/22	–	–	–	0/5	–	–
Cox. B4	SN	0/22	–	–	–	0/3	–	–
Cox. B5	SN	3/22	–	–	–	0/5	–	–
Cox. B6	SN	0/18	–	–	–	0/3	–	–
Echo 1	SN	0/22	–	–	–	0/6	–	–
Echo 3	HI	0/17	1/21	0/26	0/22	0/8	0/7	4/9
Echo 4	CF	0/34	–	–	–	–	–	–
Echo 6	SN	0/28	–	–	–	0/4	–	–
Echo 7	HI	0/19	16/25	11/27	7/22	0/9	0/8	–
Echo 9	SN	0/22	–	–	–	0/3	–	–
Echo 11	HI	0/17	0/21	0/26	1/22	0/8	0/7	2/9
Echo 12	HI	4/22	5/28	0/27	1/22	3/9	0/8	0/9
Echo 13	HI	0/17	0/21	0/26	0/22	0/8	0/7	0/9
SV4	SN	1/20	–	–	–	0/6	–	–
SV16	HI	0/20	3/20	0/20	–	0/8	1/8	–
SV19	SN	1/22	–	–	–	0/5	–	–
SV45	HI	0/19	0/21	1/28	1/34	0/9	0/7	0/9
SV49	SN	1/21	–	–	–	0/4	–	–
A13	SN	–	–	–	–	0/6	–	–
Poxvirus								
Vaccinia	HI	0/12	0/16	0/27	0/34	0/4	0/8	–
Monkey pox	HI	0/12	–	1/28	0/34	–	0/8	–
Reovirus								
Reovirus 1	HI	3/21	22/28	13/27	6/22	4/9	5/8	3/9
Reovirus 2	HI	3/21	22/28	19/27	6/22	3/9	1/8	1/9
Reovirus 3	HI	2/14	19/21	19/27	5/33	2/7	7/8	4/9
SV12	HI	3/21	22/28	–	–	1/8	8/8	–
SV59	HI	3/21	20/20	10/20	–	3/9	–	–
Miscellaneous								
Rubella	HI	7/15	4/11	10/28	21/34	–	1/8	–
LCM	CF	1/17	0/28	0/28	0/22	0/6	0/8	0/9
Marburg	CF	0/17	0/25	–	–	–	0/8	–
SHF	CF	–	0/25	–	–	0/4	0/8	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Number of sera positive/number of sera tested.
[c] Not done (–).

Blacklow et al. (30). Of the four recognized adeno-associated virus types, only type 4 is considered to be simian in origin.

As seen in Table 4, human sera were found to have antibody to all the simian adenoviruses tested except SV1. Hull (158) reported 10 of 80 human sera to have low levels (1:2 to 1:20) of antibody to SV1. On the other hand, a pool of human gamma globulin was observed to neutralize SV1, SV20, and SV25 but not SV11, SV15, SV17, SV23, and SV27. Aulisio et al. (16) had previously reported that human sera collected in New Guinea ranged from 67 to 82% positive for SV20 antibody, depending upon the ages of the donors. Of 42 sera collected in the U.S., 8 had antibody to this virus. These findings are of interest inasmuch as this virus is highly oncogenic for newborn hamsters, producing a lymphoma-like tumor. Furthermore, Hull (158) indicated that a lymphoma-like tumor exists in New Guinea but no nonhuman primates naturally occur there.

Arboviruses

Considerable attention has been given to the use of monkeys and apes for the study of arbo-

TABLE 8. *Antibody to human and simian viruses in baboon sera obtained immediately after capture in Kenya (Fig. 1)*[a]

Antigen	Serology test	Year and site									
		1963	1964	1966			1968				
				1	2	3	1	2	3	4	5
Adenovirus											
Group antigen	CF	0/27[b]	1/25	0/5	0/15	0/12	0/17	0/20	0/10	0/24	0/25
Ad12	SN	0/23	0/24	–[c]	–	–	–	–	–	–	–
Ad12 (tumor)	CF	0/26	0/40	0/5	0/19	0/22	0/18	0/20	0/11	5/8	5/25
SV1	SN	0/15	3/22	–	–	–	–	–	–	–	–
SV15	SN	0/26	–	–	1/25	6/25	–	–	–	–	–
SV23	SN	0/24	0/24	–	0/25	0/25	–	–	–	–	–
SA7	SN	7/25	18/25	–	–	–	–	–	–	–	–
SA7 (tumor)	CF	0/26	0/38	0/5	0/19	0/22	1/18	0/20	0/11	10/19	6/25
V340	SN	3/23	5/24	–	10/25	9/25	–	–	–	–	–
Arbovirus											
EE	CF	0/47	0/34	0/3	0/16	0/13	0/18	0/20	0/10	6/22	0/24
WE	CF	0/47	0/34	0/3	0/16	0/13	0/18	0/20	0/10	0/23	0/24
SLE	CF	0/25	0/16	0/4	0/17	0/19	1/18	0/20	0/10	4/21	2/25
Colorado tick	CF	–	0/5	–	–	–	–	–	–	0/21	0/22
Yellow fever		–	–	–	–	–	–	–	–	–	–
Herpesvirus											
H. hominis	CF	0/47	0/34	0/3	0/16	0/13	0/16	–	0/11	2/10	0/21
H. hominis	SN					44/44[d]					
H. simiae	SN					13/46[d]					
H. tamarinus	SN					0/37[d]					
SA8	SN					42/42[d]					
Myxovirus											
Influenza A (PR8)	CF	0/19	2/18	0/3	1/12	0/10	1/11	0/14	0/8	0/17	0/22
Influenza A (PR8)	HI	2/30	0/38	0/4	0/16	1/14	0/25	0/20	1/11	22/24	22/25
Influenza A_1 (FM1)	HI	1/30	0/38	0/4	0/16	0/14	0/25	0/20	0/11	0/24	0/25
Influenza A_2 (Jap)	HI	15/30	0/38	1/4	6/16	1/14	1/25	2/20	0/11	2/24	5/25
Influenza B (Lee)	CF	0/19	4/18	0/3	0/12	0/10	1/11	0/14	0/8	0/17	0/22
Influenza B (Lee)	HI	3/30	0/38	0/4	0/6	0/14	0/25	1/20	0/11	1/24	2/25
Measles (rubeola)	CF	0/26	0/40	0/5	0/19	0/23	0/18	0/20	0/11	0/22	0/25
Measles (rubeola)	HI	0/71	0/42	0/5	0/24	0/17	0/25	0/20	0/11	0/25	0/25
Mumps	CF	0/47	9/36	0/4	5/17	0/13	0/18	0/20	0/11	1/22	0/25
Mumps	HI	2/25	7/13	0/5	0/17	1/17	0/25	3/20	1/11	1/25	2/25
Parainfluenza 1	CF	0/24	0/25	0/5	0/15	0/12	0/17	1/25	0/10	0/24	0/25
Parainfluenza 1	HI	0/23	0/11	0/4	0/16	0/16	1/20	1/20	0/11	0/24	1/25
Parainfluenza 2	CF	0/24	2/25	0/4	0/15	1/12	0/17	0/20	0/10	1/24	0/25
Parainfluenza 2	HI	0/23	0/11	0/4	0/16	0/16	1/25	0/20	0/11	2/24	0/25
Parainfluenza 3	CF	0/24	0/25	0/4	1/15	0/12	0/17	0/20	0/10	1/25	0/25
Parainfluenza 3	HI	0/23	0/11	0/4	0/16	0/16	24/25	20/20	11/11	23/24	25/25
Respiratory syncytial	CF	0/24	0/25	0/4	0/15	0/12	0/17	0/20	0/10	0/24	0/25
SV5	HI	0/22	0/22	–	–	–	–	–	–	–	–
SV41	HI	0/18	2/18	–	–	–	–	–	–	–	–
Foamy 1		–	–	–	–	–	–	–	–	–	–
Foamy 2		–	–	–	–	–	–	–	–	–	–
Foamy 3	SN	5/24	–	–	–	–	–	–	–	–	–
Papovavirus											
SV40	SN	0/24	0/24	–	–	–	–	–	–	–	–

TABLE 8—*Continued*

Antigen	Serology test	Year and site									
		1963	1964	1966			1968				
				1	2	3	1	2	3	4	5
Picornavirus											
Polio 1	SN	0/26	0/24	–	0/25	1/25	0/25	0/22	0/11	0/24	0/25
Polio 2	SN	0/26	0/24	–	0/25	1/25	0/37	0/23	0/11	0/24	0/25
Polio 3	SN	8/23	0/23	–	0/25	0/24	0/37	0/23	0/11	0/24	0/25
Cox. A9	SN	0/42	0/24	–	0/25	0/25	0/25	0/20	0/10	0/23	–
Cox. A20	HI	2/30	0/39	0/5	1/17	0/17	5/22	5/17	4/10	1/25	2/21
Cox. B1	SN	7/26	1/24	–	0/25	0/25	–	–	–	–	–
Cox. B2	SN	1/26	0/24	–	0/25	2/25	0/25	0/20	0/11	1/23	1/25
Cox. B3	SN	0/53	0/20	–	0/25	0/25	0/25	1/20	0/11	0/19	0/25
Cox. B4	SN	0/45	0/22	–	0/25	0/24	0/25	0/20	0/11	0/24	0/25
Cox. B5	SN	0/48	1/19	–	0/25	1/25	0/25	1/19	0/12	0/24	0/24
Cox. B6	SN	0/16	0/22	–	0/25	0/25	0/25	0/20	0/11	0/24	0/24
Echo 1	SN	2/22	0/24	–	0/24	0/25	0/25	0/20	0/11	0/24	0/24
Echo 3	HI	11/30	37/41	0/5	1/17	0/17	6/23	4/18	4/11	1/25	1/21
Echo 4	CF	–	–	–	–	–	–	–	–	0/21	0/22
Echo 6	SN	0/39	0/11	–	0/25	0/25	0/25	0/20	0/11	0/24	1/25
Echo 7	HI	26/34	35/41	2/5	2/17	1/17	22/25	19/19	11/11	11/22	6/9
Echo 9	SN	0/38	0/17	–	0/25	0/25	0/25	0/20	0/11	0/23	0/25
Echo 11	HI	7/30	11/39	0/5	1/17	0/17	5/21	8/18	5/11	0/25	1/21
Echo 12	HI	17/35	25/42	0/5	2/15	4/17	2/25	0/19	0/11	0/22	0/8
Echo 13	HI	1/30	10/39	0/5	2/17	0/17	0/22	5/18	4/11	1/25	1/21
SV4	SN	1/25	2/24	–	–	–	–	–	–	–	–
SV16	HI	1/30	0/8	0/5	2/24	1/17	11/22	9/17	4/11	0/23	0/10
SV19	SN	0/24	2/23	–	–	–	–	–	–	–	–
SV45	HI	3/30	3/25	0/5	0/24	0/17	1/25	0/20	1/10	0/25	0/25
SV49	SN	8/24	9/22	–	–	–	–	–	–	–	–
A13	SN	0/23	0/24	–	–	–	–	–	–	–	–
Poxvirus											
Vaccinia	HI	0/18	0/10	–	0/24	–	0/24	0/18	0/11	0/25	0/25
Monkey pox	HI	0/16	1/10	0/5	0/24	–	0/21	1/17	0/10	5/20	10/22
Reovirus											
Reovirus 1	HI	–	19/42	0/5	1/15	11/17	3/25	1/19	0/11	2/25	0/23
Reovirus 2	HI	–	12/42	0/5	1/15	6/17	1/25	0/19	0/11	0/25	0/23
Reovirus 3	HI	25/30	10/35	2/5	10/24	5/17	8/22	9/17	2/11	–	3/15
SV12	HI	1/30	0/8	0/5	7/24	6/17	2/22	1/17	1/11	2/23	0/13
SV59	HI	2/30	15/42	–	1/15	5/17	–	–	–	–	–
Miscellaneous											
Rubella	HI	2/18	1/8	0/5	0/16	0/24	0/24	4/17	1/11	0/16	1/24
LCM	CF	0/25	16/36	0/4	0/17	0/16	0/18	2/20	1/10	0/24	0/25
Marburg	CF	0/22	3/7	0/5	2/45	6/33	2/16	0/20	0/4	3/20	4/25
SHF	CF	0/21	0/6	0/5	0/40	0/36	0/19	0/17	0/10	0/22	0/25

[a] See Table 4, footnote *a*, for abbreviations.
[b] Number of sera positive/number of sera tested.
[c] Not done (–).
[d] Not separated by site of capture.

virus infections either as model systems or for sentinel purposes. There is, however, very little information providing data on the prevalence of arbovirus infections in simians either in nature or in captivity. Many of the early monkey and ape studies were concerned with yellow fever. Within the past 10 to 15 years, some consideration has been given to the other arboviruses. An interesting comment in this regard was that of Elton, who in 1953 proposed the "installation of non-immune

FIGURE 1

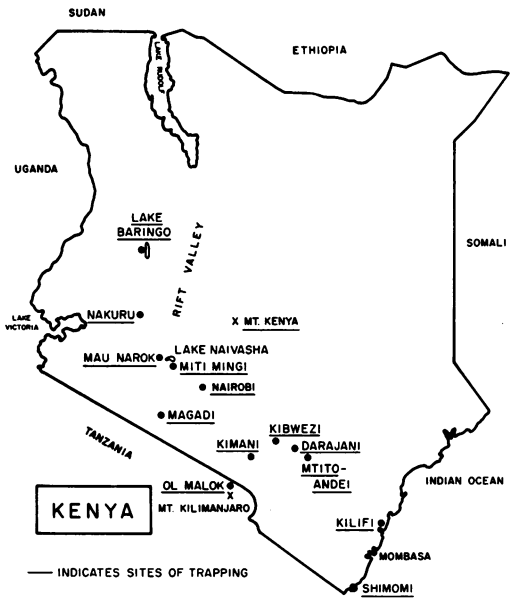

FIG. 1. *Kenya, Africa, and baboon trapping sites.*

sentinel monkeys, preferably *Macaca rhesus*" in an attempt to detect the progress of yellow fever northward through Central America.

In Africa, Haddow (116) demonstrated that galagos (*G. crassicaudatus lasiotis*) in Kenya had yellow fever antibody whereas nine baboons and less than 2% of "assorted other monkeys" were lacking this antibody. Taylor and his co-workers (330) in the Sudan determined that the baboon (*Papio* sp.) and grivet monkey (*C. aethiops*) had a high prevalence of yellow fever antibody, but the galago (*G. senegalensis*) did not. These findings suggest species differences in susceptibility to yellow fever virus.

The presence or absence of antibody to a number of arboviruses in baboon sera was studied by HI tests in this laboratory (183). Included herein were: EE New Jersey, WE Fleming, Chikungunya Chick L, Louping ill DXLIV, Sindbis Ar 1055, Semliki RI-1, Guaroa J-C2, West Nile AR248, Yellow Fever Asibi, Jap BG8924, Langat TP21, SLE Fla P-15, MVE 11A, Marituba Be An 15, and Dengue II Tr 1751. All were negative except one, which was positive for yellow fever. CF testing of these same sera indicated that two had antibody for EE.

This lack of yellow fever antibody in presumably vaccinated baboons led to another study attempting to ascertain effectiveness of yellow fever vaccine in this animal (185). It was soon evident that the vaccine was sufficiently effective, but mishandling in its usage led to rapid deterioration and resulting loss in potency.

Sera collected from a number of different species of monkeys maintained in Lagos, Nigeria, and Poona, India, were examined for antibody to representative arboviruses by Shah and Southwick (302). Included in this group of monkeys were: free-living *M. mulatta* and captive *E. patas*, *C. tantalus*, *C. mona*, *C. nictitans*, *M. leucophaeus*, *C. erythrogaster*, *C. torquatus*, *M. radiata*, and *P. entellus*. These sera were all negative to dengue 1, Chikungunya, and Japanese B encephalitis. Deinhardt and his collaborators (61) tested marmosets (cotton top and white lipped tamarins) for antibody to Western encephalitis (WE) and Eastern encephalitis (EE) virus, also with negative results.

United States-born and wild-born chimpanzee, gorilla, rhesus, African green, orangutan, and baboon sera were examined by Harrison et al. (121) for antibody to Chikungunya and related viruses (Semliki Forest, O'nyong nyong, Mayora) and reported that 26% of these sera had neutralizing antibody to one or more of these antigens. Included among the positive animals were four United States-born chimpanzees which would suggest infection by serologically related viruses residing in this country. Our findings (197) on sera from several of these same animals, that antibody to EE was present, would tend to substantiate this suggestion. Boorman and Draper (38) tested *E. patas*, *C. mona*, and *C. aethiops* sera for neutralizing antibody to Pongola, Bunyamwera, and Chikungunya viruses with all three species positive for Chikungunya. Pongola virus antibody was found in two of the *C. mona* monkeys. Schwartz and Allen (294) suggested that serological procedures (HI, CF, SN) gave more reliable indications of infection with Bunyamwera and Germiston viruses than did clinical response.

Herpesviruses

In 1934, Sabin and Wright (289) reported the occurrence of a fatal human case as a result of a rhesus monkey bite and subsequent infection with a member of this virus group (*H. simiae*, B virus). Since then, considerable attention has been focused on these viruses. Continued investigations into the relationship of herpesviruses to disease processes has substantiated this original concern. Lack of a relationship between herpesvirus antibody and susceptibility was demonstrated by Burnet et al. (44) and Van Rooyen and Rhodes (343). Burnet et al. (44) demonstrated antibody development without evidence of clinical disease. Burnet et al. (44) also noted the antigenic rela-

TABLE 9. *Antibody to human and simian viruses in captive baboon sera*[a]

Antigen	Serology test	SFRE[b]		Laboratory no. 4		Laboratory no. 5	Laboratory no. 15	(Gelada baboons)	
		Wild born	Captive born	1968	1969			Laboratory no. 4	Laboratory no. 26
Adenovirus									
Group antigen	CF	0/28[c]	1/17	0/3	–[d]	0/15	1/2	0/10	–
Ad12	SN	0/24	1/25	–	–	0/20	–	0/10	0/8
Ad12 (tumor)	CF	0/13	0/20	0/3	–	1/15	0/2	0/10	–
SV1	SN	3/24	2/24	–	–	–	–	–	1/7
SV15	SN	1/24	4/25	–	–	–	–	–	–
SV23	SN	3/23	14/23	–	–	–	–	1/7	–
SA7	SN	5/25	15/25	–	–	–	–	–	–
SA7 (tumor)	CF	0/13	0/20	0/3	–	1/15	0/2	0/10	–
V340	SN	4/24	5/17	–	–	–	–	–	0/7
Arbovirus									
EE	CF	0/30	0/22	0/3	–	0/21	0/2	0/10	–
WE	CF	2/30	1/22	0/3	–	0/21	0/2	0/10	–
SLE	CF	0/13	1/22	0/3	–	0/21	0/2	0/10	–
Colorado tick	CF	–	–	–	–	0/15	–	0/9	–
Yellow fever		–	–	–	–	–	–	–	–
Herpesvirus									
H. hominis	CF	0/30	5/22	0/3	–	0/21	0/2	0/10	–
H. hominis	SN	18/25[e]		–	–	11/50	–	–	–
H. simiae	SN	–	–	–	–	12/56	–	–	–
H. tamarinus	SN	0/27		–	–	0/38	–	–	–
SA8	SN	5/26		–	–	3/38	–	–	–
Myxovirus									
Influenza A (PR8)	CF	0/13	3/19	0/3	–	0/15	1/1	0/10	–
Influenza A (PR8)	HI	0/16	0/19	0/3	0/1	0/7	0/2	0/8	0/11
Influenza A_1 (FM1)	HI	0/16	0/19	0/3	0/1	0/7	0/2	0/8	0/11
Influenza A_2 (Jap)	HI	0/16	0/19	0/3	0/1	0/7	1/2	0/8	0/11
Influenza B (Lee)	CF	1/12	3/19	0/3	–	0/15	1/1	0/10	0/11
Influenza B (Lee)	HI	0/16	0/19	0/3	0/1	0/7	0/2	0/8	0/11
Measles (rubeola)	CF	0/15	0/21	1/3	–	2/15	–	0/10	–
Measles (rubeola)	HI	29/103	1/53	0/3	0/2	11/24	2/2	0/10	0/13
Mumps	CF	1/30	1/22	0/3	–	0/21	0/2	0/10	–
Mumps	HI	2/15	0/21	0/3	0/2	1/23	1/2	0/9	–
Parainfluenza 1	CF	0/25	0/18	0/3	–	0/15	1/2	0/10	–
Parainfluenza 1	HI	0/16	0/19	0/3	0/2	0/18	0/2	0/8	–
Parainfluenza 2	CF	2/25	0/18	0/3	–	0/15	0/2	0/10	–
Parainfluenza 2	HI	0/16	0/19	0/3	0/2	0/17	0/2	0/8	–
Parainfluenza 3	CF	1/25	1/18	0/3	–	1/15	1/2	0/10	–
Parainfluenza 3	HI	10/16	0/19	0/3	0/2	5/18	0/2	2/8	–
Respiratory syncytial	CF	0/25	0/18	0/3	–	0/15	0/2	0/10	–
SV5	HI	13/24	15/24	–	–	–	–	–	–
SV41	HI	1/24	0/24	–	–	–	–	–	–
Foamy 1		–	–	–	–	–	–	–	–
Foamy 2	SN	–	8/21	–	–	–	–	–	–
Foamy 3	SN	6/45	16/20	–	–	–	–	–	–
Papovavirus									
SV40	SN	0/24	0/24	–	–	1/24	–	–	0/8
Picornavirus									
Polio 1	SN	0/23	0/25	–	–	–	–	–	0/13
Polio 2	SN	0/24	0/24	–	–	–	–	–	0/13
Polio 3	SN	0/24	0/24	–	–	–	–	–	2/13

TABLE 9—*Continued*

Antigen	Serology test	SFRE[b]		Laboratory no. 4		Laboratory no. 5	Laboratory no. 15	(Gelada baboons)	
		Wild born	Captive born	1968	1969			Laboratory no. 4	Laboratory no. 26
Cox. A9	SN	0/24	0/25	–	–	–	–	–	0/6
Cox. A20	HI	0/15	0/21	0/3	0/2	1/23	0/2	0/9	0/13
Cox. B1	SN	0/24	5/25	–	–	–	–	–	0/9
Cox. B2	SN	2/24	1/25	–	–	–	–	–	3/13
Cox. B3	SN	0/23	0/24	–	–	–	–	–	0/6
Cox. B4	SN	1/24	0/23	–	–	–	–	–	0/6
Cox. B5	SN	2/24	4/24	–	–	–	–	–	0/6
Cox. B6	SN	0/20	0/24	–	–	–	–	–	0/6
Echo 1	SN	2/23	1/24	–	–	–	–	–	0/7
Echo 3	HI	2/30	19/21	0/3	2/2	2/23	2/2	0/9	0/13
Echo 4	CF	–	–	–	–	–	–	–	0/9
Echo 6	SN	0/7	0/17	–	–	–	–	–	0/5
Echo 7	HI	0/63	0/37	0/3	2/2	8/24	0/2	3/9	–
Echo 9	SN	0/13	0/18	–	–	–	–	–	0/5
Echo 11	HI	1/15	2/21	0/3	0/2	1/23	1/2	0/9	1/13
Echo 12	HI	1/99	1/76	0/3	0/2	0/24	0/2	0/9	0/13
Echo 13	HI	0/15	2/21	0/3	0/2	1/23	0/2	0/9	1/13
SV4	SN	0/24	1/24	–	–	–	–	–	0/9
SV16	HI	5/15	3/19	0/3	–	1/20	1/2	0/10	–
SV19	SN	1/25	2/25	–	–	–	–	–	1/8
SV45	HI	0/17	0/21	0/3	0/2	1/24	0/2	0/10	–
SV49	SN	11/24	1/23	–	–	–	–	–	1/9
A13	SN	2/24	11/21	–	–	–	–	–	0/9
Poxvirus									
Vaccinia	HI	0/13	0/21	0/3	0/2	0/15	0/2	0/9	–
Monkey pox	HI	0/12	0/20	0/3	0/2	0/2	0/2	1/9	–
Reovirus									
Reovirus 1	HI	5/15	17/21	0/3	0/2	0/24	0/2	0/9	1/13
Reovirus 2	HI	2/15	14/21	0/3	1/2	0/24	0/2	0/9	2/13
Reovirus 3	HI	6/15	9/21	3/3	0/2	8/24	2/2	5/9	–
SV12	HI	6/15	8/19	0/3	–	0/20	0/2	0/10	–
SV59	HI	3/15	13/21	–	–	–	–	–	2/13
Miscellaneous									
Rubella	HI	0/14	1/20	0/3	0/2	5/23	0/2	0/10	–
LCM	CF	2/13	3/22	0/3	0/2	0/21	0/2	0/10	–
Marburg	CF	0/13	0/18	–	–	0/18	0/2	0/10	–
SHF	CF	0/13	0/18	–	–	–	–	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] This group of animals bled upon capture and then again after 6 to 9 months in captivity.
[c] Number of sera positive/number of sera tested.
[d] Not done (–).
[e] These sera not separated; represent random sampling of both wild- and captive-born animals.

tionship of B virus, herpes simplex, and pseudorabies virus. Cross-reactions among the herpesviruses contribute to difficulties in the diagnosis of infections of this group as well as to an understanding of much of the epidemiology surrounding the spread of these viruses. It is conceivable that *H. hominis* and *H. simiae* may have been the same virus at one time, subsequent passage through different primate hosts being responsible for the differences in pathogenicity now observed. *H. simiae* in macaques is important primarily as a hazard to man and possibly other animals (including simian species other than *Macaca*) rather than its natural host. Herpesviruses in their natural hosts usually produce inapparent or latent infections rather than overt disease. The

TABLE 10. *Antibody to human and simian viruses in baboon sera followed serially from time of capture over a 6-month period*[a]

Antigen	Serology test	Sampling no. 1	2	3	4
Adenovirus					
Group antigen	–[b]	–	–	–	–
Ad12	–	–	–	–	–
Ad12 (tumor)	–	–	–	–	–
SV1	–	–	–	–	–
SV15	–	–	–	–	–
SV23	–	–	–	–	–
SA7	–	–	–	–	–
SA7 (tumor)	–	–	–	–	–
V340	–	–	–	–	–
Arbovirus					
EE	CF	0/10[c]	0/3	0/3	1/17
WE	CF	0/10	0/3	0/3	1/17
SLE	CF	0/10	0/2	0/3	0/18
Colorado tick	CF	0/7	0/9	0/4	–
Yellow fever	–	–	–	–	–
Herpesvirus					
H. hominis	CF	1/10	1/3	0/3	1/13
H. simiae	–	–	–	–	–
H. tamarinus	–	–	–	–	–
SA8	–	–	–	–	–
Myxovirus					
Influenza A (PR8)	HI	0/24	0/2	0/4	1/18
Influenza A_1 (FM1)	HI	1/24	0/2	0/4	1/18
Influenza A_2 (Jap)	HI	0/24	0/2	0/4	4/18
Influenza B (Lee)	HI	0/24	0/2	0/4	1/18
Measles (rubeola)	HI	0/24	0/2	0/4	0/18
Mumps	HI	0/24	0/2	2/4	12/18
Parainfluenza 1	HI	0/24	0/2	0/4	0/18
Parainfluenza 2	HI	0/24	0/2	0/4	0/18
Parainfluenza 3	HI	14/24	0/2	0/4	1/18
Respiratory syncytial	CF	0/12	0/3	0/3	0/17
SV5	HI	0/21	–	–	20/22
SV41	HI	0/21	–	–	0/22
Foamy 1	–	–	–	–	–
Foamy 2	–	–	–	–	–
Foamy 3	–	–	–	–	–
Papovavirus					
SV40	–	–	–	–	–
Picornavirus					
Polio 1	–	–	–	–	–
Polio 2	–	–	–	–	–
Polio 3	–	–	–	–	–
Cox. A9	–	–	–	–	–
Cox. A20	–	–	–	–	–
Cox. B1	–	–	–	–	–
Cox. B2	–	–	–	–	–
Cox. B3	–	–	–	–	–
Cox. B4	–	–	–	–	–
Cox. B5	–	–	–	–	–
Cox. B6	–	–	–	–	–
Echo 1	–	–	–	–	–
Echo 3	HI	6/22	1/1	2/3	10/17
Echo 4	CF	0/8	0/9	0/4	–
Echo 7	HI	24/24	2/2	4/4	11/17
Echo 9	–	–	–	–	–
Echo 11	HI	3/22	1/1	0/3	4/17
Echo 12	HI	1/24	0/2	1/4	1/17
Echo 13	HI	0/22	0/1	0/3	3/17
SV4	–	–	–	–	–
SV16	–	–	–	–	–
SV19	–	–	–	–	–
SV45	HI	0/24	0/2	0/4	0/17
SV49	–	–	–	–	–
A13	–	–	–	–	–
Poxvirus					
Vaccinia	HI	1/15	–	0/2	0/12
Monkey pox	HI	8/15	–	1/2	6/12
Reovirus					
Reovirus 1	HI	3/23	0/2	1/4	13/16
Reovirus 2	HI	0/23	0/2	0/4	5/15
Reovirus 3	HI	6/22	1/2	1/3	8/18
SV12	–	–	–	–	–
SV59	–	–	–	–	–
Miscellaneous					
Rubella	HI	0/24	0/2	0/4	0/18
LCM	CF	3/14	1/3	1/4	1/17
Marburg	–	–	–	–	–
SHF	–	–	–	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Not done (–).
[c] Number of sera positive/number of sera tested.

presence of antibody to *H. simiae* has been reported in a variety of monkeys by several different investigators (44, 165, 287). Antibody to B virus was reported by Endo et al. (75) in three species of macaques maintained in Japan: *M. fuscata*, *M. cyclopis*, and *M. irus*.

The close antigenic relationship between herpes simplex and B virus has been alluded to above. Examination of the literature, however, indicates conflicting reports of this relationship. Hull and

TABLE 11. *Antibody to human and simian viruses in rhesus monkey sera*[a]

Antigen	Serology test	Laboratory no.										
		SFRE	Laboratory no. 3			4	9	10	19	20	22	23	27
			1965	1967	1969								
Adenovirus													
Group antigen	CF	1/14[b]	3/19	1/17	0/22	2/24	2/25	14/24	1/24	–[c]	0/20	2/16	–
Ad12	SN	1/19	–	–	–	–	–	–	–	–	–	–	–
Ad12 (tumor)	CF	0/14	0/13	0/17	–	0/26	3/27	0/25	–	–	–	–	–
SV1	SN	1/18	2/18	–	–	–	–	–	–	–	–	–	–
SV15	SN	–	7/19	–	–	–	–	–	–	–	–	–	–
SV23	SN	8/19	10/19	–	–	–	–	–	–	–	–	–	–
SA7	SN	2/23	–	–	–	–	–	–	–	–	–	–	–
SA7 (tumor)	CF	–	–	–	–	–	–	–	–	–	–	–	–
V340	SN	3/18	1/18	–	–	–	–	–	–	–	–	–	–
Arbovirus													
EE	CF	0/25	0/12	0/17	0/12	0/22	0/25	1/25	2/22	–	0/19	0/15	0/4
WE	CF	1/25	0/12	0/17	0/11	0/22	0/25	0/25	2/22	–	0/18	0/16	0/4
SLE	CF	2/19	4/16	0/17	0/13	1/23	0/25	0/25	0/22	–	0/19	0/15	0/4
Colorado tick	CF	–	0/8	0/13	0/21	0/14	0/12	–	0/14	–	5/20	0/18	0/4
Yellow fever		–	–	–	–	–	–	–	–	–	–	–	–
Herpesvirus													
H. hominis	CF	0/25	0/12	0/17	0/8	0/25	2/25	0/25	1/6	–	0/18	4/11	0/5
H. hominis	SN	8/41					24/44[d]						
H. simiae	SN	2/25					24/44[d]						
H. tamarinus	SN	–					4/42[d]						
SA8	SN	0/42					11/40[d]						
Myxovirus													
Influenza A (PR8)	CF	0/19	0/14	0/17	0/7	0/23	0/19	0/12	0/15	–	0/20	0/2	0/3
Influenza A (PR8)	HI	0/28	5/19	0/17	1/23	0/27	0/27	0/23	4/25	–	0/20	0/21	0/5
Influenza A_1 (FM1)	HI	0/28	2/19	0/17	0/23	0/27	0/27	0/23	1/25	–	0/20	0/21	0/5
Influenza A_2 (Jap)	HI	0/28	1/19	0/17	0/23	0/27	0/27	0/23	3/25	–	0/20	0/21	0/5
Influenza B (Lee)	CF	0/19	0/14	0/17	–	0/23	0/19	0/12	0/7	–	0/20	–	0/3
Influenza B (Lee)	HI	0/28	1/19	0/17	0/23	0/27	0/27	0/23	0/25	–	0/20	0/21	0/5
Measles (rubeola)	CF	5/14	4/13	0/17	–	1/26	3/27	29/34	–	–	–	–	–
Measles (rubeola)	HI	21/27	1/19	13/17	24/24	11/28	7/26	–	23/23	–	7/19	11/19	4/4
Mumps	CF	0/25	0/12	0/17	6/14	0/26	1/25	2/25	6/26	–	0/19	6/17	0/4
Mumps	HI	1/15	2/14	0/17	9/23	5/28	5/26	7/23	1/26	–	0/20	5/21	1/5
Parainfluenza 1	CF	0/14	0/2	2/17	0/22	1/24	4/25	1/24	0/25	–	0/20	0/17	0/4
Parainfluenza 1	HI	0/15	0/14	0/16	0/23	0/27	1/27	0/25	0/25	–	0/20	0/21	0/5
Parainfluenza 2	CF	0/14	0/2	0/17	–	1/24	1/25	0/24	1/20	–	2/20	3/8	0/4
Parainfluenza 2	HI	0/15	0/14	6/17	23/23	0/27	0/27	3/25	6/25	–	6/20	5/21	3/5
Parainfluenza 3	CF	1/14	0/2	3/17	13/22	14/24	1/25	6/24	13/22	–	3/20	6/7	2/2
Parainfluenza 3	HI	15/15	12/14	15/16	23/23	23/27	7/27	9/25	23/25	–	0/20	5/21	5/5
Respiratory syncytial	CF	0/14	0/2	0/17	0/22	0/24	0/25	0/24	5/24	–	0/20	6/8	0/4
SV5	HI	16/18	–	8/16	17/23	–	–	–	14/24	–	2/20	4/21	3/4
SV41	HI	0/17	–	0/16	0/22	–	–	–	0/24	–	0/20	0/21	0/4
Foamy 1	SN	–	7/14	–	–	–	–	–	–	–	–	–	–
Foamy 2	SN	–	8/14	–	–	–	–	–	–	–	–	–	–
Foamy 3	SN	–	8/16	–	–	–	–	–	–	–	–	–	–

TABLE 11—*Continued*

Antigen	Serology test	Laboratory no.											
		SFRE	Laboratory no. 3			4	9	10	19	20	22	23	27
			1965	1967	1969								
Papovavirus													
SV40	SN	6/18	3/19	–	–	–	–	–	–	–	–	–	–
Picornavirus													
Polio 1	SN	1/19	–	–	–	–	–	–	–	–	–	–	–
Polio 2	SN	0/18	–	–	–	–	–	–	–	–	–	–	–
Polio 3	SN	0/14	–	–	–	–	–	–	–	–	–	–	–
Cox. A9	SN	0/14	–	–	–	–	–	–	–	–	–	–	–
Cox. A20	HI	0/25	0/19	0/16	0/24	0/20	0/27	0/22	0/26	–	0/20	2/19	0/5
Cox. B1	SN	0/17	–	–	–	–	–	–	–	–	–	–	–
Cox. B2	SN	3/18	–	–	–	–	–	–	–	–	–	–	–
Cox. B3	SN	0/21	0/17	–	–	–	–	–	–	–	–	–	–
Cox. B4	SN	0/18	0/11	–	–	–	–	–	–	–	–	–	–
Cox. B5	SN	0/18	0/15	–	–	–	–	–	–	–	–	–	–
Cox. B6	SN	0/16	0/13	–	–	–	–	–	–	–	–	–	–
Echo 1	SN	2/19	–	–	–	–	–	–	–	–	–	–	–
Echo 3	HI	0/25	1/19	2/16	4/24	0/30	0/27	4/22	10/26	–	1/20	15/19	1/5
Echo 4	CF	–	0/9	0/13	0/21	0/14	0/13	–	0/14	–	0/20	0/18	0/4
Echo 6	SN	0/15	–	–	–	–	–	–	–	–	–	–	–
Echo 7	HI	4/27	3/19	0/17	5/21	7/25	4/27	4/23	17/26	–	0/20	8/19	3/5
Echo 9	SN	0/15	–	–	–	–	–	–	–	–	–	–	–
Echo 11	HI	0/25	3/19	1/16	1/24	0/30	0/27	2/22	1/26	–	0/20	8/19	0/5
Echo 12	HI	1/25	12/19	0/17	0/21	0/25	0/27	0/23	0/26	–	0/20	0/19	0/5
Echo 13	HI	1/25	2/19	0/16	0/24	0/30	3/27	2/21	1/26	–	0/20	8/19	0/5
SV4	SN	–	–	–	–	–	–	–	–	–	–	–	–
SV16	HI	0/26	5/19	4/17	–	2/28	3/27	–	–	–	–	–	–
SV19	SN	7/18	–	–	–	–	–	–	–	–	–	–	–
SV45	HI	1/26	2/19	2/17	1/24	1/27	3/26	2/23	1/26	–	0/20	2/21	0/5
SV49	SN	4/18	–	–	–	–	–	–	–	–	–	–	–
A13	SN	0/16	–	–	–	–	–	–	–	–	–	–	–
Poxvirus													
Vaccinia	HI	1/15	0/10	0/15	0/24	5/27	0/24	5/25	0/25	–	0/19	0/21	1/5
Monkey pox	HI	1/15	–	–	0/24	7/27	0/24	–	1/25	–	0/19	1/21	1/5
Reovirus													
Reovirus 1	HI	20/25	14/18	5/17	4/24	7/25	8/26	0/25	7/26	–	12/20	2/18	0/5
Reovirus 2	HI	3/23	3/18	0/17	1/24	3/25	0/26	2/25	3/26	–	1/20	2/18	0/5
Reovirus 3	HI	19/24	3/19	2/15	7/24	24/29	15/26	11/25	8/25	–	7/20	12/18	1/5
SV12	HI	22/26	7/19	6/17	–	12/28	14/27	–	–	–	–	–	–
SV59	HI	3/25	3/18	–	–	–	–	–	–	–	–	–	–
Miscellaneous													
Rubella	HI	2/8	3/15	1/16	8/24	13/26	10/27	1/25	3/26	0/7	1/20	1/20	3/5
LCM	CF	1/19	5/16	4/17	0/24	0/23	0/27	0/25	0/26	–	0/20	1/20	–
Marburg	CF	0/18	–	0/5	–	–	–	1/23	1/11	0/7	–	–	–
SHF	CF	0/17	–	–	–	–	0/27	–	–	–	–	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Number of sera positive/number of sera tested.
[c] Not done (–).
[d] These represent a group of rhesus monkey sera from varied sources.

TABLE 12. *Antibody to human and simian viruses in cynomolgus and Japanese macaques*[a]

Antigen	Serology test	Cynomolgus			Japanese Mac.
		Laboratory no. 5	Laboratory no. 9	Laboratory no. 19	Laboratory no. 17
Adenovirus					
Group antigen	CF	10/42[b]	0/3	1/27	2/47
Ad12	SN	–[c]	–	–	–
Ad12 (tumor)	CF	0/21	0/2	–	0/44
SV1	SN	–	–	–	–
SV15	SN	0/25	–	–	–
SV23	SN	–	–	–	–
SA7	SN	–	–	–	–
SA7 (tumor)	CF	0/21	0/2	–	–
V340	SN	9/22	–	–	–
Arbovirus					
EE	CF	1/42	0/3	0/26	16/43
WE	CF	2/42	0/3	0/26	17/43
SLE	CF	1/42	0/3	0/26	1/43
Colorado tick	CF	0/39	0/1	0/16	–
Yellow fever		–	–	–	–
Herpesvirus					
H. hominis	CF	1/32	0/3	4/16	0/9
H. hominis	SN		14/35[d]		–
H. simiae	SN		10/44[d]		–
H. tamarinus	SN		2/37[d]		–
SA8	SN		1/40[d]		–
Myxovirus					
Influenza A (PR8)	CF	0/33	0/2	0/11	0/1
Influenza A (PR8)	HI	1/39	0/4	1/31	11/48
Influenza A_1 (FM1)	HI	0/39	0/4	0/31	3/48
Influenza A_2 (Jap)	HI	1/39	0/4	1/31	11/48
Influenza B (Lee)	CF	1/33	0/2	0/10	1/1
Influenza B (Lee)	HI	1/39	0/4	1/31	5/48
Measles (rubeola)	CF	0/22	1/2	–	–
Measles (rubeola)	HI	44/48	0/4	29/32	36/48
Mumps	CF	21/42	1/3	10/26	36/43
Mumps	HI	11/37	0/4	2/42	10/48
Parainfluenza 1	CF	2/42	2/3	0/28	0/47
Parainfluenza 1	HI	0/42	0/4	2/30	0/48
Parainfluenza 2	CF	4/41	0/3	6/24	6/47
Parainfluenza 2	HI	0/43	0/4	15/30	4/48
Parainfluenza 3	CF	19/41	0/3	17/26	32/47
Parainfluenza 3	HI	33/42	0/3	17/30	22/48
Respiratory syncytial	CF	0/42	0/3	0/26	0/47
SV5	HI	11/23	–	18/24	–
SV41	HI	0/23	–	0/24	–
Foamy 1	SN	–	–	–	–
Foamy 2	SN	–	–	–	–
Foamy 3	SN	–	–	–	–
Papovavirus					
SV40	SN	–	–	–	–
Picornavirus					
Polio 1	SN	1/25	–	–	–
Polio 2	SN	3/25	–	–	–
Polio 3	SN	0/25	–	–	–
Cox. 49	SN	0/25	–	–	–
Cox. A20	HI	6/41	0/4	0/32	6/46
Cox. B1	SN	0/25	–	–	–
Cox. B2	SN	0/25	–	–	–
Cox. B3	SN	0/25	–	–	–
Cox. B4	SN	0/18	–	–	–
Cox. B5	SN	0/12	–	–	–
Cox. B6	SN	0/11	–	–	–
Echo 1	SN	0/11	–	–	–
Echo 3	HI	22/41	0/4	23/42	17/46
Echo 4	CF	0/39	0/2	0/16	–
Echo 6	SN	1/25	–	–	–
Echo 7	HI	31/47	0/4	26/32	39/48
Echo 9	SN	0/25	–	–	–
Echo 11	HI	6/41	0/4	2/32	5/46
Echo 12	HI	7/47	0/4	4/32	10/48
Echo 13	HI	8/41	0/4	4/32	1/46
SV4	SN	–	–	–	–
SV16	HI	3/22	0/4	–	–
SV19	SN	–	–	–	–
SV45	HI	2/48	0/4	0/32	8/48
SV49	SN	–	–	–	–
A13	SN	–	–	–	–
Poxvirus					
Vaccinia	HI	0/41	0/4	1/32	0/44
Monkey pox	HI	0/44	0/4	4/32	3/44
Reovirus					
Reovirus 1	HI	9/40	0/4	13/31	27/48
Reovirus 2	HI	1/40	0/4	7/31	1/48
Reovirus 3	HI	15/36	0/3	10/43	24/32
SV12	HI	2/22	0/4	–	–
SV49	HI	–	–	–	–
Miscellaneous					
Rubella	HI	4/47	0/4	2/32	0/48
LCM	CF	0/44	0/4	1/31	0/48
Marburg	CF	3/28	–	3/12	24/40
SHF	CF	0/16	0/2	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Number of sera positive/number of sera tested.
[c] Not done (–).
[d] Represent a random sampling of *M. irus* sera.

Nash (162) reported that 10% of newly captured rhesus monkeys had antibody. Keeble et al. (202) tested 100 individual serum samples from rhesus monkeys with 17% positive. Burnet et al. (44) had previously demonstrated that nine of nine monkeys were positive for antibody to B virus. Antibody surveillance in a closed colony by

TABLE 13. *Antibody to human and simian viruses in vervet, patas, and talapoin sera*[a]

Antigen	Serology test	Vervet				Patas		Talapoin
		Laboratory no. 5	Laboratory no. 11	Laboratory no. 27	SFRE	Laboratory no. 4	Laboratory no. 5	Laboratory no. 11
Adenovirus								
Group antigen	CF	1/20[b]	7/30	0/10	5/65	5/39	0/24	1/21
Ad12	SN	–[c]	–	–	0/26	0/14	–	–
Ad12 (tumor)	CF	0/19	1/30	–	–	0/29	0/23	1/20
SV1	SN	–	–	–	1/26	0/3	–	–
SV15	SN	–	–	–	1/26	–	–	–
SV23	SN	–	–	–	0/26	–	–	–
SA7	SN	–	–	–	9/45	–	–	–
SA7 (tumor)	CF	1/19	1/30	–	12/25	0/29	0/23	3/20
V340	SN	–	–	–	17/26	3/7	–	–
Arbovirus								
EE	CF	0/20	0/30	0/8	0/22	0/37	0/24	0/15
WE	CF	0/20	0/30	0/7	0/22	0/36	0/24	0/15
SLE	CF	0/20	1/30	0/10	6/22	0/39	0/24	0/15
Colorado tick	CF	–	–	–	–	0/28	0/24	0/26
Yellow fever		–	–	–	–	–	–	–
Herpesvirus								
H. hominis	CF	0/20	0/28	0/5	0/22	3/36	0/24	0/8
H. hominis	SN	–	0/17	–	14/40	–	6/43	0/19
H. simiae	SN	–	3/17	–	–	–	2/27	4/19
H. tamarinus	SN	–	–	–	–	–	0/38	–
SA8	SN	–	0/17	–	33/40	21/37	8/38	1/19
Myxovirus								
Influenza A (PR8)	CF	0/20	0/29	0/3	0/22	0/32	0/24	0/7
Influenza A (PR8)	HI	0/15	6/38	0/12	17/18	0/40	1/17	6/20
Influenza A_1 (FM1)	HI	0/15	1/38	0/12	14/18	0/40	0/17	0/20
Influenza A_2 (Jap)	HI	1/15	0/38	3/12	15/18	6/40	0/17	0/20
Influenza B (Lee)	CF	0/20	1/29	0/3	0/22	1/32	0/24	0/7
Influenza B (Lee)	HI	0/15	0/38	0/12	12/18	10/40	0/17	0/20
Measles (rubeola)	CF	0/19	0/30	–	0/23	0/30	0/23	0/20
Measles (rubeola)	HI	11/23	1/41	4/12	1/36	15/39	2/24	1/21
Mumps	CF	0/20	3/30	2/11	0/22	1/39	0/24	12/20
Mumps	HI	3/23	7/30	6/11	4/25	18/42	3/23	18/20
Parainfluenza 1	CF	0/20	0/30	0/10	0/65	2/39	0/24	0/21
Parainfluenza 1	HI	0/21	2/45	0/12	0/25	0/40	0/20	1/21
Parainfluenza 2	CF	0/20	5/29	3/8	0/65	7/36	0/24	0/21
Parainfluenza 2	HI	18/21	2/44	1/12	0/25	3/40	19/23	0/20
Parainfluenza 3	CF	4/20	11/30	2/3	14/65	11/40	0/24	0/21
Parainfluenza 3	HI	18/21	10/44	11/12	1/25	17/40	3/20	4/20
Respiratory syncytial	CF	0/20	1/30	0/7	1/65	2/37	0/24	0/21
SV5	HI	–	3/23	7/9	6/25	5/8	–	0/16
SV41	HI	–	0/23	0/9	1/26	0/8	–	0/16
Foamy 1	SN	–	–	–	–	–	–	–
Foamy 2	SN	–	–	–	–	–	–	–
Foamy 3	SN	–	–	–	5/18	–	–	–
Papovavirus								
SV40	SN	–	–	–	2/26	1/9	–	–
Picornavirus								
Polio 1	SN	–	–	–	0/26	0/8	–	–
Polio 2	SN	–	–	–	1/26	1/8	–	–
Polio 3	SN	–	–	–	–	0/13	–	–

TABLE 13—*Continued*

Antigen	Serology test	Vervet				Patas		Talapoin
		Laboratory no. 5	Laboratory no. 11	Laboratory no. 27	SFRE	Laboratory no. 4	Laboratory no. 5	Laboratory no. 11
Cox. A9	SN	–	–	–	–	0/9	–	–
Cox. A20	HI	6/23	2/30	0/6	0/19	0/38	8/24	3/21
Cox. B1	SN	–	–	–	3/26	1/9	–	–
Cox. B2	SN	–	–	–	1/26	8/14	–	–
Cox. B3	SN	–	–	–	0/26	0/3	–	–
Cox. B4	SN	–	–	–	0/25	–	–	–
Cox. B5	SN	–	–	–	1/26	–	–	–
Cox. B6	SN	–	–	–	0/24	–	–	–
Echo 1	SN	–	–	–	1/26	3/13	–	–
Echo 3	HI	10/23	27/27	1/6	15/32	4/38	8/24	18/21
Echo 4	CF	0/14	0/28	0/12	–	0/29	0/24	0/29
Echo 6	SN	–	–	–	0/48	–	–	–
Echo 7	HI	7/23	10/30	6/12	1/20	1/41	6/24	13/20
Echo 9	SN	–	–	–	0/45	–	–	–
Echo 11	HI	8/23	3/30	0/6	3/19	0/38	7/24	2/21
Echo 12	HI	7/23	2/24	0/12	9/33	3/41	7/24	0/20
Echo 13	HI	3/23	3/30	0/6	1/19	0/38	2/24	0/21
SV4	SN	–	–	–	4/26	3/8	–	–
SV16	HI	2/22	3/24	–	0/19	0/29	0/23	7/20
SV19	SN	–	–	–	2/26	1/8	–	–
SV45	HI	1/23	0/24	0/12	0/19	1/42	1/24	2/21
SV49	SN	–	–	–	6/26	2/7	–	–
Ale	SN	–	–	–	0/26	3/8	–	–
Poxvirus								
Vaccinia	HI	0/20	0/21	2/12	2/24	0/37	0/18	0/21
Monkey pox	HI	0/20	0/27	2/12	1/24	2/32	0/20	4/21
Reovirus								
Reovirus 1	HI	7/23	17/30	3/12	5/19	28/41	2/24	1/20
Reovirus 2	HI	1/23	4/30	1/12	0/19	9/41	2/24	0/20
Reovirus 3	HI	15/23	24/24	3/12	9/18	19/42	16/24	–
SV12	HI	4/22	12/24	–	1/19	16/29	2/23	1/20
SV59	HI	–	–	–	0/19	–	–	–
Miscellaneous								
Rubella	HI	8/22	0/29	4/12	0/24	5/36	6/23	0/21
LCM	CF	0/20	0/30	0/12	5/23	0/37	0/24	0/21
Marburg	CF	7/16	5/27	1/2	2/19	–	2/23	24/34
SHF	CF	0/21	0/25	–	0/23	8/31	0/23	0/14

[a] See Table 4, footnote *a*, for abbreviations.
[b] Number of sera positive/number of sera tested.
[c] Not done (–).

Gralla and coinvestigators (110) indicated a change from 6.6 to 28% in a period of some 20 months. These findings were comparable to those obtained by Melnick and Banker (243). Shah and Southwick (302) indicated that antibodies to *H. simiae* were present in free-living adult rhesus monkeys but not in juveniles. Zeitlyonok et al. (359) found the cynomolgus monkey in Indonesia to have antibody to B virus under conditions that exclude contact with rhesus monkeys.

Forty-one baboon sera were tested previously for antibody to herpes simplex, with three animals found positive (183). Additional studies (175, 177–179, 197) have since indicated that antibody to herpes simplex may be found in many other simian sera: chimpanzee, baboon (including freshly captured animals), and various macaques. Ohwada et al. (260) found 65.1% of *C. aethiops* and 69.9% *M. irus* to have antibody to herpes simplex. Free-living rhesus monkeys from India were compared by Shah and Morrison (301) for antibody to *H. simiae* with free-ranging rhesus

TABLE 14. *Antibody to human and simian viruses in a variety of marmosets (Saguinus and Callithris sp.)*[a]

Antigen	Serology test	Laboratory no. 8	Laboratory no. 11	Laboratory no. 18	Laboratory no. 14
Adenovirus					
Group antigen	CF	0/24[b]	0/15	0/7	1/4
Ad12	SN	-[c]	–	–	–
Ad12 (tumor)	CF	–	0/22	0/6	0/13
SV1	SN	–	–	–	–
SV15	SN	–	–	–	–
SV23	SN	–	–	–	–
SA7	SN	–	–	–	–
SA7 (tumor)	CF	–	0/22	0/6	0/13
V340	SN	–	–	–	–
Arbovirus					
EE	CF	0/25	0/22	–	0/12
WE	CF	0/25	0/22	–	0/12
SLE	CF	0/25	0/22	–	0/12
Colorado tick	CF	–	0/4	–	–
Yellow fever		–	–	–	–
Herpesvirus					
H. hominis	CF	0/25	0/22	–	0/13
H. hominis	SN	–	–	–	–
H. simiae	SN	–	–	–	–
H. tamarinus	SN	–	–	–	–
SA8	SN	–	–	–	–
Myxovirus					
Influenza A (PR8)	CF	0/22	0/15	0/7	0/4
Influenza A (PR8)	HI	0/24	0/24	0/2	0/15
Influenza A_1 (FM1)	HI	0/24	0/24	0/2	0/15
Influenza A_2 (Jap)	HI	8/24	3/24	2/2	15/15
Influenza B (Lee)	CF	0/22	0/15	0/7	0/4
Influenza B (Lee)	HI	0/22	1/24	2/2	15/15
Measles (rubeola)	CF	0/30	–	–	0/13
Measles (rubeola)	HI	0/43	0/24	0/8	–
Mumps	CF	0/25	0/22	1/2	0/13
Mumps	HI	0/24	–	–	23/29
Parainfluenza 1	CF	0/24	0/15	0/2	0/4
Parainfluenza 1	HI	0/24	0/24	0/7	0/15
Parainfluenza 2	CF	0/23	2/13	0/2	0/4
Parainfluenza 2	HI	0/24	0/24	0/7	0/15
Parainfluenza 3	CF	0/24	0/15	2/2	0/4
Parainfluenza 3	HI	0/24	0/24	0/7	4/15
Respiratory syncytial	CF	0/24	0/15	0/7	0/4
SV5	HI	–	–	–	10/15
SV41	HI	–	–	–	0/15
Foamy 1	SN	–	–	–	–
Foamy 2	SN	–	–	–	–
Foamy 3	SN	–	–	–	–
Papovavirus					
SV40	SN	–	–	–	–
Picornavirus					
Polio 1	SN	–	–	–	–
Polio 2	SN	–	–	–	–
Polio 3	SN	–	–	–	–
Cox. A9	SN	0/46	2/22	–	0/15
Cox. A20	HI	–	–	–	–
Cox. B1	SN	–	–	–	–
Cox. B2	SN	–	–	–	–
Cox. B3	SN	–	–	–	–
Cox. B4	SN	–	–	–	–
Cox. B5	SN	–	–	–	–
Cox. B6	SN	–	–	–	–
Echo 1	SN	–	–	–	–
Echo 3	HI	0/46	0/22	–	0/15
Echo 4	CF	–	–	–	–
Echo 6	SN	–	–	–	–
Echo 7	HI	0/46	1/22	0/7	0/12
Echo 9	SN	–	–	–	–
Echo 11	HI	1/46	1/22	–	0/15
Echo 12	HI	0/46	1/22	0/7	0/12
Echo 13	HI	0/45	1/22	–	0/15
SV4	SN	–	0/4	–	–
SV16	HI	–	–	–	–
SV19	SN	1/44	4/24	–	0/14
SV45	HI	0/43	–	–	1/24
SV49	SN	–	–	–	–
A13	SN	–	–	–	–
Poxvirus					
Vaccinia	HI	–	2/20	0/8	0/15
Monkey pox	HI	–	4/20	2/8	0/15
Reovirus					
Reovirus 1	HI	2/46	1/24	0/8	0/15
Reovirus 2	HI	0/46	0/24	0/8	0/15
Reovirus 3	HI	7/36	19/24	3/8	0/15
SV12	HI	–	0/24	–	0/14
SV59	HI	–	–	–	–
Miscellaneous					
Rubella	HI	2/12	–	5/8	0/33
LCM	CF	0/31	0/24	–	1/11
Marburg	CF	0/16	0/14	0/6	0/3
SHF	CF	–	0/21	–	0/12

[a] See Table 4, footnote *a*, for abbreviations.

[b] Number of sera positive; denominator = number of sera tested.

[c] Not done (-).

TABLE 15. *Antibody to viruses of human and simian origin in squirrel monkeys*[a]

Antigen	Serology test	Laboratory no. 18	Laboratory no. 21	Laboratory no. 22	Laboratory no. 11
Adenovirus					
Group antigen	CF	–[b]	0/2[c]	1/11	0/10
Ad12	SN	–	–	–	–
Ad12 (tumor)	CF	–	–	–	0/16
SV1	SN	–	–	–	–
SV15	SN	–	–	–	–
SV23	SN	–	–	–	–
SA7	SN	–	–	–	–
SA7 (tumor)	CF	–	–	–	0/16
V340	SN	–	–	–	–
Arbovirus					
EE	CF	–	0/1	0/5	0/15
WE	CF	–	0/1	0/5	0/15
SLE	CF	–	0/1	0/7	0/15
Colorado tick	CF	–	–	0/14	0/15
Yellow fever		–	–	–	–
Herpesvirus					
H. hominis	CF	–	0/1	0/1	0/16
H. hominis	SN	–	–	–	–
H. simiae	SN	–	–	–	–
H. tamarinus	SN	–	–	–	–
SA8	SN	–	–	–	–
Myxovirus					
Influenza A (PR8)	CF	–	0/2	0/13	0/13
Influenza A (PR8)	HI	1/13	0/5	1/22	1/19
Influenza A_1 (FM1)	HI	1/13	0/5	3/22	0/19
Influenza A_2 (Jap)	HI	10/13	1/5	16/22	14/19
Influenza B (Lee)	CF	–	0/2	0/13	0/13
Influenza B (Lee)	HI	10/13	0/5	0/22	0/19
Measles (rubeola)	CF	–	–	–	–
Measles (rubeola)	HI	2/16	0/2	12/21	2/19
Mumps	CF	–	0/1	1/13	0/15
Mumps	HI	1/13	–	1/22	5/18
Parainfluenza 1	CF	–	0/2	0/14	0/13
Parainfluenza 1	HI	1/14	0/5	0/20	0/20
Parainfluenza 2	CF	–	2/2	0/10	0/9
Parainfluenza 2	HI	0/14	0/5	0/20	0/20
Parainfluenza 3	CF	–	0/1	0/13	0/12
Parainfluenza 3	HI	11/14	3/5	5/20	2/20
Respiratory syncytial	CF	–	0/2	0/14	0/13
SV5	HI	–	0/4	0/23	0/22
SV41	HI	–	0/4	0/23	0/22
Foamy 1	SN	–	–	–	–
Foamy 2	SN	–	–	–	–
Foamy 3	SN	–	–	–	–
Papovavirus					
SV40	SN	–	–	–	–
Picornavirus					
Polio 1	SN	–	–	–	–
Polio 2	SN	–	–	–	–
Polio 3	SN	–	–	–	–
Cox. A9	SN	–	–	–	–
Cox. A20	HI	–	0/1	0/20	0/19
Cox. B1	SN	–	–	–	–
Cox. B2	SN	–	–	–	–
Cox. B3	SN	–	–	–	–
Cox. B4	SN	–	–	–	–
Cox. B5	SN	–	–	–	–
Cox. B6	SN	–	–	–	–
Echo 1	SN	–	–	–	–
Echo 3	HI	–	0/1	0/20	0/19
Echo 4	CF	–	–	0/14	0/15
Echo 6	SN	–	–	–	–
Echo 7	HI	0/22	0/3	0/23	0/22
Echo 9	SN	–	–	–	–
Echo 11	HI	–	0/1	0/20	0/19
Echo 12	HI	0/22	0/3	0/23	0/22
Echo 13	HI	–	0/1	0/20	0/19
SV4	SN	–	–	–	–
SV16	HI	–	–	–	–
SV19	SN	–	–	–	–
SV45	HI	–	0/2	0/22	0/20
SV49	SN	–	–	–	–
A13	SN	–	–	–	–
Poxvirus					
Vaccinia	HI	2/18	1/4	7/19	10/22
Monkey pox	HI	2/18	4/4	14/19	17/22
Reovirus					
Reovirus 1	HI	7/16	2/3	4/15	8/22
Reovirus 2	HI	9/16	1/3	3/3	3/22
Reovirus 3	HI	4/15	3/3	3/21	1/22
SV12	HI	–	–	–	12/22
SV59	HI	–	–	–	–
Miscellaneous					
Rubella	HI	7/11	0/4	6/23	5/22
LCM	CF	–	–	0/20	0/20
Marburg	CF	0/2	0/1	–	–
SHF	CF	–	–	–	0/14

[a] See Table 4, footnote *a*, for abbreviations.
[b] Not done (–).
[c] Number of sera positive/number of sera tested.

on Cayo Santiago and in captivity at the San Juan, Puerto Rico, laboratory. Antibody prevalence was as follows: 72% in the Cayo Santiago group, 33% in the captive animals, and 15% in animals in India. Of the latter animals, antibody was detected only in the older animals.

TABLE 16. *Antibody to human and simian viruses in capuchin and woolly monkeys*[a]

Antigen	Serology test	Capuchin			Woolly	
		Lab no. 6	Lab no. 18	Lab no. 21	Lab no. 10	Lab no. 18
Adenovirus						
Group antigen	CF	–[b]	–	–	0/1[c]	0/6
Ad12	SN	–	–	–	–	–
Ad12 (tumor)	CF	–	–	–	–	0/3
SV1	SN	–	–	–	–	–
SV15	SN	0/36	–	–	–	–
SV23	SN	–	–	–	–	–
SA7	SN	–	–	–	–	–
SA7 (tumor)	CF	–	–	–	–	0/3
V340	SN	0/36	–	–	–	–
Arbovirus						
EE	CF	–	–	0/3	0/1	–
WE	CF	–	–	0/3	0/1	–
SLE	CF	–	–	0/3	0/1	–
Colorado tick	CF	–	–	–	–	–
Yellow fever		–	–	–	–	–
Herpesvirus						
H. hominis	CF	–	–	0/3	0/1	–
H. hominis	SN	–	–	–	–	–
H. simiae	SN	–	–	–	–	–
H. tamarinus	SN	–	–	–	–	–
SA8	SN	–	–	–	–	–
Myxovirus						
Influenza A (PR8)	CF	–	–	0/1	–	0/6
Influenza A (PR8)	HI	0/6	0/3	0/5	0/1	0/1
Influenza A_1 (FM1)	HI	0/6	1/3	0/5	0/1	0/1
Influenza A_2 (Jap)	HI	1/6	3/3	0/5	0/1	1/1
Influenza B (Lee)	CF	–	–	0/1	–	0/6
Influenza B (Lee)	HI	0/6	3/3	0/5	0/1	1/1
Measles (rubeola)	CF	–	–	–	–	–
Measles (rubeola)	HI	0/37	0/3	0/1	0/1	0/2
Mumps	CF	–	–	0/3	0/1	–
Mumps	HI	0/8	0/3	0/5	0/1	0/1
Parainfluenza 1	CF	–	–	0/3	0/1	0/6
Parainfluenza 1	HI	0/6	0/3	0/5	0/1	0/2
Parainfluenza 2	CF	–	–	0/3	0/1	0/6
Parainfluenza 2	HI	0/6	0/3	0/5	0/1	0/2
Parainfluenza 3	CF	–	–	0/3	0/1	0/6
Parainfluenza 3	HI	0/6	3/3	1/5	0/1	1/2
Respiratory syncytial	CF	–	–	0/2	–	1/6
SV5	HI	–	–	0/5	–	–
SV41	HI	–	–	0/5	–	–
Foamy 1	SN	–	–	–	–	–
Foamy 2	SN	–	–	–	–	–
Foamy 3	SN	–	–	–	–	–
Papovavirus						
SV40	SN	0/3	–	–	–	–
Picornavirus						
Polio 1	SN	–	–	–	–	–
Polio 2	SN	–	–	–	–	–
Polio 3	SN	–	–	–	–	–
Cox. A9	SN	–	–	–	–	–
Cox. A20	HI	0/21	–	0/1	–	–
Cox. B1	SN	–	–	–	–	–
Cox. B2	SN	–	–	–	–	–
Cox. B3	SN	–	–	–	–	–
Cox. B4	SN	–	–	–	–	–
Cox. B5	SN	–	–	–	–	–
Cox. B6	SN	–	–	–	–	–
Echo 1	SN	–	–	–	–	–
Echo 3	HI	0/22	–	0/5	0/1	–
Echo 4	CF	–	–	–	–	–
Echo 6	SN	0/36	–	–	–	–
Echo 7	HI	0/27	0/4	0/9	0/1	0/6
Echo 9	SN	0/36	–	–	–	–
Echo 11	HI	0/22	–	0/1	0/1	–
Echo 12	HI	0/37	0/4	0/9	0/1	0/6
Echo 13	HI	0/22	–	0/1	0/1	–
SV4	SN	–	–	–	–	–
SV16	HI	0/37	–	–	–	–
SV19	SN	–	–	–	–	–
SV45	HI	0/19	–	0/1	–	–
SV49	SN	–	–	–	–	–
A13	SN	–	–	–	–	–
Poxvirus						
Vaccinia	HI	–	0/7	0/7	0/1	–
Monkey pox	HI	–	0/1	1/1	2/6	2/6
Reovirus						
Reovirus 1	HI	0/37	0/5	0/2	–	2/6
Reovirus 2	HI	0/37	0/5	0/2	–	2/6
Reovirus 3	HI	18/25	3/4	1/2	0/1	5/6
SV12	HI	–	–	–	0/1	–
SV59	HI	–	–	–	–	–
Miscellaneous						
Rubella	HI	–	0/3	0/1	–	4/4
LCM	CF	–	–	–	0/1	–
Marburg	CF	–	–	0/4	–	0/6
SHF	CF	–	–	–	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Not done (–).
[c] Number of sera positive; denominator = number of sera tested.

Sabin (287) had originally concluded that *H. hominis* and *H. simiae* were distinct entities, although a relationship based upon serum neutralization results was indicated. Pierce et al. (268) and Nagler and Klotz (254) had found

individuals with antibody to herpes simplex but not to herpes B. Other investigators (44, 47, 163, 243, 342) found human sera with anti-B virus immune globulins. It was generally conceded that these individuals were reflecting antibody to *H. hominis* rather than indicating a previous exposure to B virus.

As seen in Table 2, other simian viruses have

TABLE 17. *Antibody to human and simian viruses in owl, howler, and spider monkey sera*[a]

Antigen	Serology test	Owl	Howler		*A. geoffroyi*—Spider[b]			*A. geoffroyi*[b]	Red spider[b]
		Laboratory no. 15	Laboratory no. 6[c]	Laboratory no. 6[d]	Laboratory no. 6	Laboratory no. 18	Laboratory no. 21	Laboratory no. 6	Laboratory no. 6
Adenovirus									
Group antigen	CF	–[e]	0/3[f]	–	–	0/1	0/7	0/1	–
Ad12	SN	–	–	–	–	–	–	–	–
Ad12 (tumor)	CF	0/7	–	–	–	0/1	–	–	–
SV1	SN	–	–	–	–	–	–	–	–
SV15	SN	–	0/25	0/16	0/13	–	–	0/24	0/10
SV23	SN	–	–	–	–	–	–	–	–
SA7	SN	–	–	–	–	–	–	–	–
SA7 (tumor)	CF	0/7	–	–	–	0/1	–	–	–
V340	SN	–	0/25	0/16	0/14	–	–	0/25	0/10
Arbovirus									
EE	CF	–	0/3	–	–	–	0/7	–	–
WE	CF	–	0/3	–	–	–	0/7	–	–
SLE	CF	–	0/3	–	–	–	0/7	–	0/1
Colorado tick	CF	–	–	–	–	–	–	–	–
Yellow fever		–	–	–	–	–	–	–	–
Herpesvirus									
H. hominis	CF	–	0/3	–	–	–	0/7	0/1	–
H. hominis	SN	–	–	–	–	–	–	–	–
H. simiae	SN	–	–	–	–	–	–	–	–
H. tamarinus	SN	–	2/40[g]		–	–	–	–	–
SA8	SN	–	–	–	–	–	–	–	–
Myxovirus									
Influenza A (PR8)	CF	–	0/3	–	–	0/1	0/5	0/1	–
Influenza A (PR8)	HI	–	0/6	0/1	0/3	–	0/8	0/8	1/2
Influenza A_1 (FM1)	HI	–	0/6	0/1	0/3	–	0/8	0/8	0/2
Influenza A_2 (Jap)	HI	–	1/6	0/1	0/3	–	0/8	2/8	1/2
Influenza B (Lee)	CF	–	0/3	–	–	0/1	0/5	0/1	–
Influenza B (Lee)	HI	–	0/6	0/1	0/3	–	0/8	0/8	0/2
Measles (rubeola)	CF	–	–	–	–	–	–	–	–
Measles (rubeola)	HI	0/9	0/40	0/17	0/14	–	0/3	0/49	0/10
Mumps	CF	–	0/3	–	–	–	0/7	0/1	–
Mumps	HI	–	2/5	0/1	0/2	–	4/8	1/8	0/2
Parainfluenza 1	CF	–	0/3	–	–	0/1	0/7	0/1	–
Parainfluenza 1	HI	–	0/6	0/1	0/3	–	0/8	0/8	0/2
Parainfluenza 2	CF	–	0/2	–	–	0/1	0/6	–	–
Parainfluenza 2	HI	–	0/6	0/1	0/3	–	0/8	0/8	0/2
Parainfluenza 3	CF	–	0/3	–	–	0/1	0/7	0/1	–
Parainfluenza 3	HI	–	1/6	0/1	0/3	–	7/8	0/8	0/2
Respiratory syncytial	CF	–	0/3	–	–	0/1	0/5	0/1	–
SV5	HI	–	–	–	–	–	0/7	–	–
SV41	HI	–	–	–	–	–	0/7	–	–
Foamy 1	SN	–	–	–	–	–	–	–	–
Foamy 2	SN	–	–	–	–	–	–	–	–
Foamy 3	SN	–	–	–	–	–	–	–	–
Papovavirus									
SV40	SN	–	0/15	0/16	0/14	–	–	0/25	0/10

TABLE 17—*Continued*

Antigen	Serology test	Owl	Howler		*A. geoffroyi*—Spider[b]			*A. geoffroyi*[b]	Red spider
		Laboratory no. 15	Laboratory no. 6[c]	Laboratory no. 6[d]	Laboratory no. 6	Laboratory no. 18	Laboratory no. 21	Laboratory no. 6	Laboratory no. 6
Picornavirus									
Polio 1	SN	–	–	–	–	–	–	–	–
Polio 2	SN	–	–	–	–	–	–	–	–
Polio 3	SN	–	–	–	–	–	–	–	–
Cox. A9	SN	–	–	–	–	–	–	–	–
Cox. A20	HI	–	0/26	0/8	0/4	–	0/3	0/25	0/4
Cox. B1	SN	–	–	–	–	–	–	–	–
Cox. B2	SN	–	–	–	–	–	–	–	–
Cox. B3	SN	–	–	–	–	–	–	–	–
Cox. B4	SN	–	–	–	–	–	–	–	–
Cox. B5	SN	–	–	–	–	–	–	–	–
Cox. B6	SN	–	–	–	–	–	–	–	–
Echo 1	SN	–	–	–	–	–	–	–	–
Echo 3	HI	–	0/26	3/8	0/4	–	0/3	0/25	0/4
Echo 4	CF	–	–	–	–	–	–	–	–
Echo 6	SN	–	0/25	0/16	2/14	–	–	0/25	0/10
Echo 7	HI	0/10	0/39	0/17	0/4	0/1	0/4	0/49	0/10
Echo 9	SN	–	0/23	0/16	0/14	–	–	0/25	0/10
Echo 11	HI	–	0/26	0/8	0/4	–	0/3	0/25	0/4
Echo 12	HI	0/12	0/39	0/17	0/14	0/1	0/4	0/49	0/12
Echo 13	HI	–	0/26	2/8	0/4	–	0/3	0/25	0/4
SV4	SN	–	–	–	–	–	–	–	–
SV16	HI	–	0/14	0/7	1/14	–	–	6/49	0/10
SV19	SN	–	–	–	–	–	–	–	–
SV45	HI	–	0/24	0/8	0/6	–	0/3	0/22	0/3
SV49	SN	–	–	–	–	–	–	–	–
A13	SN	–	–	–	–	–	–	–	–
Poxvirus									
Vaccinia	HI	0/8	–	–	–	1/1	2/6	–	–
Monkey pox	HI	0/8	–	–	–	1/1	6/6	–	–
Reovirus									
Reovirus 1	HI	1/8	0/39	0/17	1/14	0/1	1/4	0/49	2/10
Reovirus 2	HI	2/8	0/39	0/17	0/14	0/1	1/4	0/49	1/10
Reovirus 3	HI	5/10	3/26	4/8	1/6	0/1	1/3	16/31	2/4
SV12	HI	–	0/40	0/17	7/14	–	–	6/49	2/10
SV59	HI	–	–	–	–	–	–	–	–
Miscellaneous									
Rubella	HI	1/4	–	–	–	1/1	0/6	–	–
LCM	CF	–	0/3	–	–	–	–	0/1	–
Marburg	CF	0/8	–	–	–	0/1	0/7	–	–
SHF	CF	–	–	–	–	–	–	–	–

[a] See Table 4, footnote *a*, for abbreviations.
[b] Designated by the contributing laboratory (no. 6) as separate groups.
[c] *Alouatta palliata.*
[d] Genus and species not designated.
[e] Not done (–).
[f] Number of sera positive/number of sera tested.
[g] Random sampling of howler sera.

been since described: SA8 (223, 224); *Herpesvirus tamarinus*—marmoset herpes virus (MHV), *H. platyrrhinae* (139, 246); spider monkey virus (SMV; reference 158; Lennette, *unpublished data*). Because of common characteristics, these viruses have been collected into one group (group A); SA6 (223, 224) resembles cytomegaloviruses and is separated into group B. Other herpesviruses

include a number isolated from different South American monkeys, primarily through the efforts of Melendez and his collaborators (237, 241): *H. saimiri*, *H. aotus*, *H. saguinus*. Outbreaks of fatal disease in African green and patas monkeys have resulted in the isolation of still another herpesvirus (53, 234). Only limited information is available regarding existence in primates of antibodies to these viruses.

Deinhardt et al. (61) assayed a group of South American monkeys for SN antibody to *H. tamarinus* and found *Saimiri* sp., *Ateles* sp., *C. albifrons*, *S. fuscicollis*, *S. nigricollis*, and *S. mystax* to have antibody (14.3 to 53%), whereas *C. apella*, *Aotus* sp., *Lagothrix* sp., and *S. oedipus* were negative. More positive sera were observed among the older animals than the juveniles. Findings as regards *H. tamarinus* on sera from 515 New World monkeys had been reported by Holmes et al. (139). Antibody to this virus was also described by Sheldon and Ross (304) in *Saimiri*, *Callithrix*, *Ateles*, *Cebus*, and *Lagothrix* species.

Examination of human sera by Hampar et al. (120) revealed an antigenic relationship between herpes simplex and SA8. It is interesting that another herpes-like virus (EB virus) has come out of Africa, this in the form of an intracellular particle (76) found in a malignant lymphoma first described by Burkitt (41). Henle and Henle (132) and Armstrong et al. (14) indicated a widespread distribution of antibody to these herpes-like particles in Burkitt's lymphoma cells grown in culture. Antibody (CF) in five species of nonhuman primates to EB virus was described by Gerber and Birch (98). Antibody to EB virus was quite prevalent in chimpanzee, rhesus, cynomolgus, and African green monkey sera but not in baboon. It was suggested that this may reflect a cross-reaction with other herpesviruses.

In the course of studies with EB virus, it was demonstrated that infectious mononucleosis was serologically related (100, 133, 258). Gerber and Rosenblum (101) examined rhesus sera for antibody to EB virus-infectious mononucleosis with the finding that 50% of the sera had such globulins. Several investigators previously attempted, without success, to demonstrate the susceptibility of nonhuman primates to the causative agent of infectious mononucleosis (22, 168, 354, 355). The relationship between EB virus and infectious mononucleosis prompted Gerber et al. (99) to repeat these experimental attempts in rhesus monkeys without avail.

Serological studies in this laboratory on the herpesvirus group were originally limited to herpes simplex (197). Although our recently expanded studies (Table 18) are not complete, they demonstrate the antigenic relationships of

TABLE 18. *Serum-neutralization antibody in primate sera to selected herpesviruses*

Animal	Laboratory no.	Virus			
		SA8	*Herpesvirus tamarinus*	*H. hominis*	*H. simiae*
Chimpanzee	2	3/84[a]	0/38	2/38	0/38
Baboon	SFRE (Africa)	42/42	0/37	44/44	13/46
Baboon	5	3/38	0/38	11/50	12/56
Cynomolgus	31	1/40	2/37	14/38	10/44
Patas	5	8/38	0/38	6/43	2/27
"Macaques"	33	11/40	4/42	24/44	24/44
Squirrel	SFRE	–[b]	22/35	0/35	–
Galago	11	0/35	0/35	0/35	0/35

[a] Number of sera positive = number of sera tested.
[b] Not done (–).

H. hominis, *H. simiae*, and SA8 that Hull (156) had previously shown. The SA8 virus is probably not as closely related to *H. simplex* and B virus as they are to one another. Antibody to *H. tarmarinus* is only rarely found in Old World monkeys and this is presumed to be the result of either cross-infection or antigenic overlapping. The one New World monkey (squirrel) thus far extensively tested was found to be approximately 63% infected. These surveys are continuing, and preliminary serological evidence continues to uphold this species and geographic distribution of antibody. The galago was devoid of antibody to all four herpesviruses, a finding we have also noted as related to other viruses.

Myxoviruses

There are actually only three viruses that have been recovered from monkeys and apes that satisfy the biological characteristics for inclusion in this group of viruses: SV5, SV41, and SA10. The seven foamy viruses have many of these same characteristics but do not agglutinate erythrocytes or produce inclusion bodies in infected cells. Further, their morphology differs from that of the myxoviruses. Until more data are available on the foamy viruses, they will be included with this virus group. Hsiung (147) suggests that these and the measles (rubeola) virus be classified under the pseudomyxoviruses. Hull (156) refers to the foamy viruses as "myxovirus-like." In all likelihood, the foamy viruses should be in a separate group with similar bovine and feline viruses. In addition to these viruses, a number of other viruses have been isolated from primates, but their relationship to these hosts are subject to question. For example, Ruckle (284, 285) recovered an agent, "monkey-intra-nuclear-inclusion agent (minia)," which she indicated to be

closely related to measles. This virus is now known to be identical to the measles virus. SV5 and SA10 also may have originated in an animal other than monkey if epidemiological and antigenic relationships continue to support present findings. Respiratory syncytial (RS) virus (249), originally recovered from a chimpanzee with coryza, is now considered to be a human agent—CCA (49). SA10 is closely related to parainfluenza type 3 in the HI test. Serological surveys have indicated a wide distribution of antibody among primates to the above viruses as well as to other myxoviruses.

The frequent occurrence of SV5 in monkey kidney cells has resulted in considerable attention being given to the relationship of this virus to the monkey. Perhaps most important is the need for information pertaining to the origin of this particular virus. Most investigators agree that newly captured animals do not have SV5 antibody (28, 153, 197, 301, 302, 339). SV5 has been recovered from man (153, 293) as well as from dogs (Florence Lief, *personal communication*). It is conceivable, therefore, that this virus may be present in simian tissues only as a result of infection after contact with man or dog (possibly another animal?) after captivity. Antibody to the parainfluenza viruses is also quite common in captive monkeys and apes, especially to type 3. Newly captured animals, however, had only infrequent or no antibody to these viruses; Shah and Southwick (302) reported that there was little evidence of infection with types 1 and 2 parainfluenza virus. Only animals with human contact had antibody: one with para-1 and one with para-2. The prevalence of antibody for type 3 parainfluenza virus was higher in adults than in juveniles. It was difficult, however, to correlate the findings with human contacts, even though these were free-living animals. Of known captive animals in Lagos, Nigeria, or Poona, India, type 3 antibody was present in *E. patas*, *C. aethiops tantalus*, *C. mona*, *C. nictitans*, and *M. mulatta*, but none of the *P. entellus* was found to be positive. A comparison of titers between human and bovine strains of parainfluenza type 3 indicated that higher titers were found with the human strains. Of 48 "monkey" sera (rhesus, cynomolgus, patas, and chimpanzee) tested by Hsiung et al. (151), 4.2, 31, and 79% were positive to types 1, 2, and 3 parainfluenza viruses, respectively. These animals were all captive and had been held in a common holding facility. Deinhardt et al. (61) failed to demonstrate antibody to these three types of parainfluenza viruses in newly arrived marmosets. Two animals in the colony for more than 1 year, however, seroconverted to types 2 and 3 (one marmoset had antibody to both types).

Involvement of monkeys and apes with measles virus has been well described since the early studies of Enders and Peebles (73). Documentation for "natural" and experimental infection of different species is readily available. Limited information is available regarding New World monkeys and rubeola, but Levy and Mirkovic (*personal communication*) have described its devastating occurrence in marmosets. Prevalence of antibody, in a variety of simians, to measles has been also well documented (28, 178, 197, 247, 260, 301, 302, 305, 357). Deinhardt et al. (61) did not observe measles antibody in approximately 50 newly arrived marmosets. Bhatt et al. (28) also failed to find measles antibody in 170 bonnet and 195 langur sera.

Influenza virus infections of nonhuman primates is unquestionably in need of study. Saslaw and Carlisle (291) briefly reviewed the use of rhesus monkeys in experimental influenza. Woolpert et al. (356) described the development of antibodies in experimentally infected rhesus monkeys. Bhatt et al. (28) found antibody to influenza (A_2/Japan 305/57) in small numbers of rhesus, bonnet, and langur sera. Deinhardt et al. (61) did not find antibody in marmosets when the sera were tested with influenza-soluble antigen types A, B, and C. We previously reported (197) influenza HI antibody to be present in a variety of monkey and ape (chimpanzee, orangutan, gibbon, baboon, and rhesus) sera to the PR8 (A_0), FM1 (A_1), Japan 305 (A_2), and Lee (B) strains of influenza. Gorilla, gelada, vervet, and certain groups of baboons and rhesus were found to be seronegative. The question of specificity was raised at that time. Recently Atoynatan and Hsiung (15), in examining baboon, rhesus, and green monkey sera for influenza antibodies (PR8, FM1, A_2/Jap/305, A_2/Taiwan/1, swine, and equine viruses) also indicated concern over the specificity of the reactions. Ohwada et al. (260) reported the prevalence of influenza antibody in *C. aethiops* to be: PR8, 23.4%; FM1, 21.7%; Adachi, 6.0%; Swine and Great Lake (B), 8.1%. In *M. irus* the findings were: PR8, 34.8%; FM1, 19.1%; Adachi, 5.6%; Swine and Great Lake, 7.9%. Serological conversions occurred in experimentally infected (A_2/Hong Kong/68) and noninfected control contact baboons (193). Heberling and Kalter (127) demonstrated that treatment of influenza-inoculated baboons with poly-IC resulted in a delay or supression of antibody. Antibody formation was prevented in uninoculated control contact animals.

Mumps virus infection of monkeys and apes occurs probably at a subclinical level, although Bloch (35) in 1934 reported development of clinical parotitis in monkeys. Hsiung et al. (151)

found 23% of an assortment of monkey sera (rhesus, patas, cynomolgus, chimpanzee) to have mumps antibody. Kalter et al. (197) found antibody to this virus in sera from chimpanzees and baboons. Gorilla, orangutan, gibbon, rhesus, and vervet sera in limited numbers were found to be negative. More recent studies (178; *unpublished data*) indicate mumps antibody to be present in the following simians: gorilla (198), chimpanzee (184), baboon, African green, rhesus, patas, cynomolgus, Formosan rock macaque, stumptail macaque, talapoin, Japanese macaque, howler, spider, and marmoset. No antibody was found in the orangutan and gibbon (Tables 4 to 17). Deinhardt et al. (61) did not find antibody in marmoset sera to mumps "S" and "V" antigens.

Only brief mention will be made of the RS virus first reported by Morris et al. (249). This isolate, chimpanzee coryza agent (CCA), was recovered from a chimpanzee with respiratory illness that occurred in a colony of 20 "normal" chimpanzees. Chanock et al. (49) described the recovery of a virus from infants with a respiratory illness which was related to the chimpanzee coryza agent. It is now conceded that this virus is probably human in origin, and chimpanzees become infected from contact with man. As seen in Tables 4 to 17, antibody to this agent has been found by us in man, chimpanzee, orangutan, rhesus, vervet, patas, and woolly monkeys. Except for chimpanzee, the number of positives were small and scattered through the colonies examined. None of the various African and Asian monkeys examined by Shah and Southwick (302) had detectable antibody to RS virus.

As indicated above, the foamy viruses are discussed here, although a number of investigators have reservations regarding their appropriate final classification. Table 2 indicates the original simian sources of the foamy viruses. The vacuolating viruses require extensive experience in their recognition and are indistinguishable except by serological methods. Stiles (324) suggested the use of CF procedures for the elimination of foamy virus-positive kidney donors (*M. mulatta, C. aethiops*). Hull (156) refers to a serological survey of human sera (Taiwan, Japan, United States) for antibody to types 1 and 2 foamy virus without an positives detected. We recently initiated the examination of monkey and ape sera to these viruses, and our results are too cursory at this time to be of any significance. As seen in the various tables, however, antibody to type 1 was found in rhesus but not in chimpanzee sera. Again, chimpanzee sera were negative for type 2 foamy virus, but antibody to this virus was present in rhesus and baboon sera. Type 3 antibody was seen in human, chimpanzee, orangutan, baboon, African green, and rhesus sera. Rogers et al. (281) indicated that chimpanzee sera had neutralizing antibody to Pan 1 and 2, which are now designated as foamy virus types 6 and 7, respectively (Table 2).

An infrequently isolated simian myxovirus, SV41, is similar in many respects biologically to SV5 even to the extent of their serological cross-reactivities (156). Human or monkey gamma globulins were reported by Hull (156) to contain no neutralizing antibody to this virus. In our survey, antibody was found to SV41 in sera from: chimpanzee, orangutan, baboon, vervet but not in man, gorilla, gibbon, rhesus, cynomolgus, patas, talapoin, marmoset, squirrel, capuchin, or spider monkeys.

In summarizing the serological data on myxovirus infections of simians, we find that there is need for more detailed studies. As indicated, however, infection and probably disease results as a consequence with a number of these viruses. More often infection is probably subclinical or only very mildly apparent. The problem of serum inhibitors, which may be additional to or different from those known to occur in human serum, may confuse interpretation of these data. It is interesting to note, in examining the results with the various influenza viruses, that the prevalence of antibody increases as one employs newer (A_2) strains of influenza viruses. This is especially true of the gorilla (Table 5), chimpanzee (Table 6), orangutan (Table 7), marmoset (Table 14), and squirrel (Table 15) monkey sera.

Papovaviruses

Simian papovaviruses include SV40 and possibly SA12. Little is known about the latter virus after its discovery by Malherbe and Harwin (224). Found only once in a vervet kidney culture, it resembles SV40 in the type of intranuclear inclusion formed but does not appear to be related. Serologically, SV40 is of greater concern to investigators employing monkeys and apes because of (i) its frequent occurrence in macaque (especially rhesus) kidney cultures and (ii) its oncogenicity for newborn hamsters (71).

The full extent of the natural occurrence of SV40 is still not clear, primarily because the majority of reports concerning its isolation from one or another species do not delineate the history of the animal providing the isolate. Thus, the report by Hsiung and Gaylord (152) on recovery of SV40 from patas monkeys must be viewed carefully, as these animals had previous contact with macaques. Meyer et al. (248) assayed sera from rhesus, cynomolgus, and African green monkeys and reported that 69% of the rhesus, 3% of the cynomolgus, and none of the green monkeys

were serologically reactive. These investigators also noted that animals with antibody were more often prone to have positive kidney cultures, and antibody-free animals had kidneys without SV40 virus. Inoculation of African green monkeys with SV40-infected cells resulted in the production of antibody (277). Stiles (324) supported the findings of Meyer et al. (248) by reporting SV40 antibody in rhesus but not grivet monkey sera. Zeitlyonok et al. (359) examined cynomolgus monkeys in Indonesia for SV40 antibody, with negative results. Similar findings for the African green monkey were reported by Chumakov et al. (51) and Chumakova et al. (52). African green monkeys and baboons maintained in contact with rhesus monkeys will convert to seropositive (52). Shah and Southwick (302) reported 100% of adult rhesus monkey sera to have antibody to this virus. Young animals were found to be only 18% serologically positive. In a follow-up of this study, Shah and Morrison (301) found 34% of the free-living rhesus in India to have SV40 antibody, whereas 81% of laboratory animals and only 1% of the Cayo Santiago animals had antibody to this virus. Hsiung et al. (150) reported that rhesus and African green monkeys serologically negative upon arrival in their laboratory later converted to positive, although the origin of the infection is not apparent.

Experimental injection of rhesus monkeys with SV40 T antigen resulted in production of antibody (300). This antibody was also detected in naturally infected rhesus. Young rhesus were more apt to have antibody than adults, as the prevalence of SV40 T antibody declined with the age of the animal. In another report, Shah et al. (303) described experimental infection of nonimmune rhesus monkeys with development of viral SN and CF antibody in all animals and T antibody in approximately 88% of these animals.

Because of the wide distribution of SV40 virus in conjunction with the various poliovirus vaccines employed (active or inactivated), the question concerning human infection with SV40 was of more than academic interest. Morris et al. (250) described subclinical infection of man after intranasal instillation of SV40 with subsequent development of antibody. Fraumeni et al. (89) reported antibody development without acute illness in recipients of poliovirus vaccine containing live SV40 virus. Shah (299) found 14 of 161 humans without histories of receiving vaccines made in monkey tissues but living in areas where rhesus monkeys were prevalent to have SV40 antibody. Individuals who worked directly with monkeys were found to be more frequently positive (10 of 37) as regards the presence of this antibody. Inactivated poliovaccine was also found by Gerber (97) to contain SV40 antigen, and many recipients of this vaccine developed antibody with titer levels remaining constant in a number for at least 3 years.

We have found (175–179, 197) SV40 antibody in human sera, especially in laboratory personnel (14 of 72 individuals). Thirty-six citizens of Kenya, however, did not have antibody. Gorilla sera (198) were negative; only 2 of 157 chimpanzee sera were found with SV40 antibody and these were both in one laboratory (184). Other monkeys and apes with SV40 antibody (Tables 4–17) were: 1 baboon in captivity of 80 animals tested, rhesus, small numbers of vervets, and patas. No antibody was seen in sera from orangutan, gibbon, newly captured baboon, and various New World monkeys.

Picornaviruses

The picornaviruses are of interest because they (poliovirus) were instrumental in precipitating the current large demand for primates in virus research and preparation of kidney cells. The simian enteroviruses (no simian rhinovirus has been described) are also among the more frequently recovered viruses from monkeys and apes. Furthermore, simian enteroviruses constitute a major challenge because of the frequent failure of the host animal to produce high-titered antibody or any antibody at all. Failure on the part of the host to produce antibody or low-titered antibody probably results from the lack of tissue invasion other than in the intestinal tract. Accordingly, virus isolations may frequently be made without detection of serum antibody (126, 138). Simian enteroviruses rarely cause latent infections. Readily recovered from the intestinal tract of animals, these viruses have received less attention than many of the other simian viruses.

In our initial serological studies with captive baboon sera (183), antibodies were found only to echovirus 18, although the survey included poliovirus types 1 to 3, coxsackieviruses B1-6 and A9, and echoviruses types 1 to 28. Chimpanzees reportedly may possess both neutralizing (245) and CF (212) antibodies to the coxsackieviruses upon arrival in the laboratory. The source of infection of these animals was not described. Kraft (211) reported the occurrence of coxsackievirus CF antibodies in sera of normal rhesus and cynomologus monkeys. Shah and Southwick (302) found that one of 47 free-living rhesus monkeys had antibody to type 2 poliovirus. In contrast, Bhatt et al. (28) found low-titered HI antibody to echovirus types 3, 7, 11, 12, and 19 to be present in sera from the bonnet, langur, and rhesus. They also indicated that 47 rhesus sera failed to neutralize rhinovirus CV30 (a human

strain). Schmidt et al. (292) were unable to find preexisting SN or CF antibody in rhesus sera to any of the human enteroviruses. Experimental infection, however, resulted in specific antibody production to coxsackieviruses B1, B3, B4, B5, B6, and A9. Initial infection produced specific CF antibody which tended to broaden with subsequent inoculations. Rhesus monkeys were used by Kamitsuka et al. (201) for the preparation of antisera to 26 group A coxsackieviruses. Many of these sera were found, however, to cross with other coxsackieviruses. Heterologous crossings such as these have been reported previously in monkeys and chimpanzees (212, 213). Kamitsuka et al. (201) also reported development of antibodies in these coxsackievirus-inoculated rhesus monkeys to several simian enteroviruses: SV2, SV6, SV16, SV18, SV19, SV26, SV35. It was suggested that these antibodies may have been due to: (i) natural infection by these viruses, (ii) contamination of coxsackievirus antigens with simian viruses, or (iii) sharing of common antigens between the simian viruses and coxsackieviruses. In a subsequent study by these investigators (236), it was determined that the simian viruses did not share antigens in common with the human group A coxsackieviruses. The encountered antibody in these monkeys was considered as related to infection either before or after arrival in the laboratory.

Hoffert, Bates, and Cheever (138) and Heberling and Cheever (126) were unable to detect antibody to simian enteroviruses in rhesus monkeys, even though these animals were shedding virus. Antibody to the three polioviruses and group B coxsackieviruses was not detected in a serological survey of marmoset sera on newly imported animals or in animals that have been in the colony for over a year (61). Surveys of several groups of monkeys and apes had indicated large numbers of chimpanzees to have antibodies to the three polioviruses, coxsackieviruses B1, B2, and A9, echoviruses 1, 7, 12, and SV19, SV49, and A13 (197). In that survey, a few orangutans were found also with antibody to echoviruses 7 and 12, SV19, and SV49. Gibbon sera were devoid of antibody except to echoviruses 3 and 12. Baboon sera, especially those obtained in Africa, varied considerably depending upon their source and test virus. Evidently, epidemics of echoviruses 3 and 7 occurred in Africa as almost 100% of the sera examined had antibody to these two viruses. Another group of baboon sera obtained during a different field trip and from other animals in Kenya were equally positive to echovirus 3 (echovirus 7 not tested). A group of vervets also had many seropositives (15 of 33) to echovirus 3, but only 1 of 20 had antibody to echovirus 7. A number of rhesus sera were found with antibody to echovirus 12. More than 50% of the patas sera had antibody to coxsackievirus B2. Additional studies with gorilla sera (198) demonstrated that most of these animals had poliovirus antibody as a result of an outbreak or vaccination of colony animals (2) The majority of these gorilla sera were serologically negative to coxsackieviruses B1 to B6 and echoviruses 3, 6, 9, 11, and 13. A small number of gorillas were found with coxsackievirus A9 and A20 antibody (these latter were conversions over a 1-year period) and to echoviruses 7 and 12. Chimpanzee virus studies (184) expanded those serological results reported previously (197) with this species. Poliovirus antibodies were detected to all three types (vaccination); however, epidemics to one or another type were detected in different laboratories housing these animals, especially poliovirus type 2. Antibodies also were seen in a few chimpanzees for coxsackieviruses A9 and B-6. The highest prevalence of positives was for the A9 viruses with animals in all five laboratories having antibody. Antibody to A20 was infrequently present, with two noteworthy exceptions. The Southwest Foundation for Research & Education (SFRE) colony of animals showed evidence of slowly converting from negative (0 of 17 chimpanzees) to 4 of 15 with antibody at 6 to 9 months after arrival. Laboratory no. 1 animals also converted from none of 16 animals seropositive in 1963 to 38 of 64 with antibody some 4 years later. Echovirus antibody was found to types 1, 3, 6, 7, 9, 11, 12, and 13, with scattered evidence of "outbreaks" or seroconversions detected in a number of contributing colonies. In confirmation of these findings were those of Ohwada et al. (260) in *C. aethiops* and *M. irus*. These investigators reported the presence of antibody in varying numbers of animals to the three polioviruses and coxsackieviruses A9, B4, and B5. The African greens also had antibody to B3 and echoviruses 4, 6, and 9. The cynomolgus monkeys did not have antibody to these four viruses. It is to be emphasized that frequently only small numbers of animals were seropositive.

Antibody was noted to several of the simian picornaviruses SV4, SV16, SV19, SV45, SV49, and A13. Differences in the numbers of positive animals, extending for SV49 from none to 9 of 52, were observed in the different colonies. As seen in Tables 4 to 17, antibody to these viruses were present in varying numbers of animals. No antibody to echovirus type 4 was ever detected. Antibody to the six simian enteroviruses was found in all species examined. SV4 and SV45 were only infrequently encountered. The results

for SV4 are in conflict with those found by Hull et al. (161).

Rhinoviruses, a subgroup of picornaviruses, have not been recovered from naturally infected monkeys and apes. Dick and Dick (64) described an outbreak of rhinovirus 31 in chimpanzees. Serological data on the animals in the study, however, indicated a number with preexisting antibody. From the data presented, it is difficult to ascertain the relationship of this antibody to the experimental conditions. Previous studies by Dick (63) had demonstrated that chimpanzees used in experimental studies with human rhinovirus types 14 and 43 were free of SN antibody to these two viruses. Likewise, Martin and Heath (230) found that vervets were without antibody to human and equine strains of rhinoviruses. The gibbon (269) also responded to human rhinoviruses (1A, 2, 14) with antibody development. Prebleedings on two animals were seronegative. We have found no antibody to human rhinoviruses in baboon sera (*unpublished data*).

Poxviruses

Recently the question has been raised (10) regarding the possibility of a reservoir for the poxviruses existing in nature among monkeys and apes, especially smallpox. In a review of the status of simians to smallpox and related viruses, Hahon (118) raised two points that were pertinent: (i) "The problem regarding the susceptibility of the simian host to the poxviruses might be clarified, if a survey were carried out to determine the extent of specific antibodies to the poxviruses that are present in different monkey populations." (ii) "That the susceptibility of different species of monkeys and their lack of uniformity of response to infection with related poxviruses may be dependent on a previous exposure to an antigenically related agent in their natural environment receives further support from the recent discoveries of the existence of a natural pox disease of monkeys." The occurrence of an outbreak of monkey pox (347) added emphasis to the need for studies of poxviruses in simians. Arita and Henderson (10) recently reviewed the situation concerning poxviruses in nonhuman primates and concluded from reports of outbreaks and epidemiological surveillance that smallpox in simians is rare, if it occurs at all.

Serological examination of nonhuman primate sera for evidence of poxvirus infection have been complicated by the reliability of available routine procedures (CF, SN, HI). In an attempt to clarify the relationship of monkeys to the human disease, an informal discussion, sponsored by the WHO Smallpox Eradication Unit, was held in Moscow in March 1969 (Participants: I. Arita, F. Fenner, R. Gispen (chairman), S. B. Gurvich, S. S. Kalter, S. S. Marennikova, G. Meiklejohn, J. Noble, Jr., G. M. Sheluchina, V. D. Soloviev, and I. Tagaya.) Serological results obtained on several thousand sera from numerous nonhuman primates (approximately 20 species) indicate a small number to have HI but not SN antibody to variola or monkey pox antigens, or to both. A large number of additional sera from cynomolgus monkeys collected in the field in Malaysia were tested by several of the participating laboratories, again with essentially negative results. Conclusions drawn from these results would suggest that the CF test is unsuitable because of anticomplementary activity. The HI test was thought to be satisfactory (experimentally infected animals respond with easily detected HI antibody), but there may be difficulties with nonspecific inhibitors in monkey sera. Furthermore, HI antibody may not persist longer than 1 year. Neutralizing antibody is more persistent, but only limited information is available on its use for obtaining the desired information. Other procedures, such as immunofluorescence and gel diffusion, have not been evaluated in epidemiological situations. Obviously further studies are required to elucidate the problem. Recently, Noble (259) tested 535 sera obtained from *E. patas*, *P. papio*, *C. aethiops*, *M. irus*, *Saimiri* sp., *L. lagothricha*, *A. paniscus*, *C. apella*, *C. capucinus*, and assorted *Macaca* sp. for HI antibody to vaccinia virus and found 26 sera to be positive in low titer. All positive animals, however, had been in contact with man. These findings indicate further that the epidemiological data obtained thus far do not support the hypothesis that a reservoir for smallpox exists in wild monkey and ape populations. Studies regarding this problem are still in progress.

As indicated above, natural poxvirus infections of nonhuman primates do occur and have been reported in a variety of monkeys and apes: rhesus, cynomolgus, other macaques, chimpanzee, gorilla, and orangutan (104, 118, 235, 270, 271, 347). España (*personal communication*) described an outbreak of monkey pox in various species of monkeys, including a number heretofore not incriminated (*Presbytis cristatus* and *M. nemestrina*). Experimental infection may also be readily induced by a number of routes, and Hahon (118) lists the poxvirus and susceptible host species. A series of studies by Wenner and his collaborators (50, 349–353) describe the clinical, virological, and immunological aspects of monkey pox invasion of rhesus and cynomolgus monkeys. Experimentally infected baboons developed clinical disease associated with antibody development to monkey poxvirus as do uninoculated

control animals maintained in the same room (128). In all these studies, good antibody responses to the infecting agent were noted. Preimmunization sera on all these experimental animals, and others, were consistently negative (57).

Two other poxviruses, Yaba (26) and Yaba-like (W. P. McNulty and C. España, *personal communication*), also warrant brief discussion, primarily because they produce extensive outbreaks in captive monkey colonies and man is moderately susceptible. Overt disease has apparently occurred only in Asian macaques and not in African simians. Antibody surveys have not been pursued to any extent. Back et al. (20) reported that the prevalence of antibody to Yaba virus was very high in Asian monkeys, but only 5 of 57 baboons were found with this antibody. Baboons born at this institution (SFRE) were free of Yaba antibody.

Reoviruses

The characteristics of the reoviruses were described by Sabin (288), along with the indication that antibody to this virus was present in monkey sera. Of the three simian reoviruses described, SV12 and SA3 appear to be very closely related to reovirus type 1, and SV59 is antigenically similar to reovirus type 2. There does not seem to be a counterpart to reovirus type 3, although Deinhardt et al. (61) reported finding this virus in marmosets. Serological surveys for the reoviruses have been minimal. Bhatt et al. (28) described antibody to all three types in bonnet, langur, and rhesus monkeys. Many of these animals had antibody to more than one of the reoviruses. Our previous serological studies (178, 184, 197–199) found antibody to these three viruses to be commonplace. Antibody to the reoviruses were frequently encountered in gorilla sera, a finding contrasting with antibody data on other viruses. Many of the chimpanzees were found with antibody to all three reoviruses, especially to type 3 at the time of capture in Africa.

A more detailed study (189) on reoviruses of primates emphasizes and expands the above. In this study, antibody was again very frequently encountered in primate sera, with type 3 antibody most prevalent. An attempt was made also to collate multiple infections with this virus group. Dual infections, and in many instances infection with all three reoviruses, were noted in many of the different species examined. Tables 4 to 17 list the findings for each of the reoviruses in the different test primates.

George and Feldman (96) examined wild and captive bonnet monkeys for reovirus antibodies, finding both groups to have approximately the same prevalence of antibody to the three serotypes, with type 2 antibody predominating. More of the captive rhesus monkeys had antibody to all three types than the bonnet monkeys, again with the majority of animals positive for type 2 (approximately 90%). Experimental inoculation of bonnet monkeys with type 3 reovirus resulted in only homotypic serological responses. No evidence regarding the extent of antibody in these animals prior to the study was given.

Miscellaneous Viruses

Antibody to viruses other than those recognized as members of established families or groups have been determined in sera of various monkeys and apes. Generally this information stems from testing the prebleedings on animals to be used experimentally, and as a consequence the series is frequently small. These data are, however, valuable as they may provide some information relative to previous infection by the agent in question. Interpreting such data may be difficult because investigators may select seronegative (for their purposes) animals and do not indicate how many positives may have been in the test group. Our laboratory has completed serological surveys for a number of unclassified viruses and the results are given in Tables 4 to 17.

Hepatitis virus. As with rubella, monkeys and apes have been employed in the virus laboratory in an attempt to develop a model system for the further understanding of the disease caused by hepatitis viruses. Evans (78) attempted to transmit an agent to nonhuman primates without success. In 1961, Hillis (135) reported on the occurrence of hepatitis in Air Force personnel associated with the handling of chimpanzees. Subsequent to this discovery, serological evidence concerning infection of this primate and others (23–25, 61, 242) has been limited by lack of a procedure applicable to such surveys. Description of an agent (Australia antigen) present in the serum of an Australian aborigine (36, 37) has provided such a tool for serological investigations and surveys of this virus infection. Results of such testing of limited numbers of nonhuman primates suggest with fair certainty that the apes (chimpanzees, gibbons, orangutans) have circulating antigen and perhaps antibody (137, 218, 272, 308). Results with monkeys are not as clear. Baboons, rhesus, vervets, marmosets, and squirrel monkeys have been tested, generally with negative results. Deinhardt (60) recently reviewed hepatitis in nonhuman primates. It seems clear that chimpanzees may be a source of human infection,

but it is not known whether infection of these apes occurs in the wild or after association with man in captivity.

Lymphocytic choriomeningitis virus. Originally isolated by Armstrong and Lillie (12) from a monkey inoculated with material from a patient with "St. Louis encephalitis," the lymphocytic choriomeningitis virus (LCM) is now known to have an extremely wide natural (primarily an inapparent infection of rodents, *Mus musculus*) and experimental host range, including various species of monkeys and apes. A previous report (197) indicated that CF antibody, although not extensive among the various nonhuman primates examined, is well distributed. Seropositives were encountered among chimpanzees of several colonies, orangutans, vervets, rhesus, and baboons. Antibody in baboons was frequently found, especially in a group of serum samples obtained during a field trip to Kenya in 1964. The significance of these findings is not clear at this time, and apparent disease has never been reported. Inasmuch as baboons (and other simians) are known to eat rodents, it is assumed that infection of these primates results from either their capturing and eating an infected animal or perhaps contamination of food supplies by mouse feces or urine.

Marburg virus. In August to September 1967, an outbreak of hemorrhagic disease occurred in Frankfurt-Marburg, Germany, and in Belgrade, Yugoslavia, in persons who had contact with African green monkeys from a common source. These individuals were all involved in handling blood and tissues of the animals or patients with the disease, but they were not animal handlers. Of 30 cases, 7 were fatal. Several reviews are available and are suggested for information on clinical and isolation findings (112, 205, 221, 310, 314, 316). Serological studies attempting to determine what monkeys and apes may be responsible for spreading or harboring this agent has led to confusion. Kissling and his collaborators (205), Kafuko et al. (171), Stojkovic et al. (325), and results obtained in this laboratory with antigen prepared by R. E. Kissling (180, 196) have found a number of simian species with CF and SN antibody to this agent. Stojkovic (325), whose laboratory was also involved in this outbreak, reported the presence of CF antibody in 90% of their surviving African green monkeys. Our results suggested a focus of infection in African simians. Humans not associated with the disease, African simians born in the United States, South American monkeys, and Asian macaques (with some exceptions) were devoid of antibody. Human convalescent sera and experimentally infected hamster sera were found to be positive. Talapoins, African greens, chimpanzees, and baboons, of the African animals, were found with antibody (Tables 4–17). More recently, examination of sera obtained from elephants, gazelles, wildebeeste, zebras, and kongoni in Africa were also found devoid of Marburg virus antibody (*unpublished data*).

Other investigators have not been able to substantiate these findings. Simpson found many of the sera supplied by us to be anticomplementary (*personal communication*). Malherbe and Strickland-Cholmeley (229) also failed to find any positives among the vervet and baboon (Chacma) sera tested by them. Perhaps another antigen and procedure (immunofluorescence) such as that suggested by Slenczka (315) will allow a better serological evaluation. Such a study is underway.

Rabies virus. Evidently rabies infection does not occur frequently in nonhuman primates, although a case of natural rabies in a laboratory monkey (rhesus) has been reported by Boulger (39). Experimental infection of several species with this virus has been mentioned above (217). Anderson and Sgouris (5) found rhesus monkeys to be lacking demonstrable serum antibody.

Rauscher murine leukemia virus. Sibal (309) demonstrated the development of antibody by tanned cell HA and microimmunodiffusion procedures in rhesus monkeys after experimental inoculation with Rauscher murine leukemia virus.

Rous sarcoma virus. Munroe and Windle (252) and, independently, Zilber et al. (360, 361) reported the development of tumors in various species of monkeys (*M. mulatta*, *M. nemestrina*, and *P. hamadryas*) after inoculation with Rous sarcoma virus. This has generated vast interest in the use of monkeys and apes as models for the study of oncogenic viruses. Studies by Morgan (248*a*) on naturally occurring Rous sarcoma virus antibody in baboons, chimpanzees, and African green monkeys were negative. Similar findings on these and other primate species have been substantiated in this laboratory (*unpublished data*). Experimental inoculation of various species of simians with Rous sarcoma virus generally produces an antibody response, although some investigators have failed to detect it (27, 48, 58, 59, 182, 200, 244, 274, 358). Additional studies in this laboratory have demonstrated the development of COFAL (complement-fixing avian leukosis) antibodies in baboons after tumor development with Rous sarcoma virus, even when the animals are on immunosuppressive regimens (200; *unpublished data*).

Rubella virus. The use of monkeys for studies with rubella virus has resulted in conflicting results, primarily from the aspect of clinical disease.

Most investigations were concerned with development of congenital anomalies and here, too, there is little uniformity of opinion. We have recently successfully produced clinical disease in baboons associated with rash and lymphadenopathy. Thus, in the course of these experiments, sera from different species of monkeys (rhesus, African greens, patas, baboons) have failed to indicate the presence of preexisting rubella antibody (4, 46, 47, 68, 113, 129, 191, 261, 267, 297, 311). Our serological surveys (177–179, 181, 184, 188, 197, 198) have found rubella antibody to be present in the following captive primates: gorilla, chimpanzee, orangutan, gibbon, baboon, African green, rhesus, patas, cynomolgus, marmoset, squirrel, and woolly monkeys. The capuchin, stumptail, Japanese macaque, Formosan rock macaque, whiteface spider, and talapoin monkeys were found to be without rubella antibody. The number of sera in many instances was small, and further study is suggested. Few of the newly captured baboons were found with antibody, but the number of captive baboons with antibody to this virus was also very small. Other groups of animals were found with prevalences of almost 100% (Tables 4–17). The chimpanzees at SFRE seroconverted to rubella virus, an event not observed in the baboons. Ohwada et al. (260) also reported antibody to rubella virus in *C. aethiops* (0.95%) and *M. irus* (5.30%). Horstmann (141) found that baboons and chimpanzees all developed antibody after infection with rubella virus derived from humans.

SA11 virus. Simian virus SA11, isolated by Malherbe and Harwin (223), is apparently not related to any other established virus except to the "O agent" isolated from abattoir wastes (226). Malherbe and Strickland-Cholmeley (226) found SN antibody to SA11 in five of six vervet monkeys as well as in sera from other animals (nonprimates).

Simian hemorrhagic fever virus. Outbreaks with high fatality rates, as a result of infection with this agent, have been reported occurring in nonhuman primate macaques (*M. mulatta, M. irus, M. nemestrina, M. assamensis* and *M. speciosa*) in several laboratories in the United States, Soviet Union, and England. Only *Macaca* sp. appear to be susceptible to simian hemorrhagic fever virus, as other primates (including man) associated with infected animals failed to develop apparent disease. Tauraso et al. (329) recently reviewed this subject. In an attempt to determine the natural source of this virus, a serological survey was performed in cooperation with N. M. Tauroso (328). As seen in Tables 4 to 17, the results were somewhat surprising in that such widely diverse species of primates—man, gorilla, chimpanzee, orangutan, gibbon, baboon, African green, rhesus, cynomolgus, patas, talapoin, stumptail, and marmosets—were consistently negative for CF antibody to simian hemorrhagic fever. One surviving animal from the original outbreak, whose serum served as a control, was positive. Recently a small number of patas monkeys were found (Table 13) with CF antibody, but SN antibody was not detected in these animals (*unpublished data*). The significance of this finding is not clear.

Vesicular stomatitis virus. CF examination of sera from a number of Panamanian monkeys—black spider (*A. fusciceps*), red spider (*A. geoffroyi*), white face (*C. capucinus*), marmoset (*S. geoffroyi*), howler (*A. palliata*), and night monkeys (*A. trivirgatus*) by Srihongse (323) and Tesh et al. (333) indicated one-third of the animals to be positive for vesicular stomatitis virus. [The genus and species reported for black spider, red spider, and marmoset are at slight variance with those recommended for these species (Table 1)].

VIRUS ISOLATIONS

Table 2 lists and classifies, according to current schema, the recognized prototype simian viruses. Numerous reviews describe these agents—their isolation, growth, and biological characteristics—in detail (147, 148, 156, 157, 178, 179, 186). There are many additional agents continuously being recovered from simian tissues or excreta. Each new simian species studied to date has yielded one or more unique viral agents. Of the more than 70 recognized simian virus serotypes, most have proven not to be highly pathogenic for either the monkey population or other animals with which they have had contact. The exceptions, on the other hand, have been devastating—Marburg virus in man and monkey, simian hemorrhagic fever in macaques, herpesviruses in man and monkey, Kyasanur forest disease in man and monkey, poxvirus in monkeys and apes (and possibly unvaccinated humans), and so on. Infection of an animal other than the natural host is frequently highly invasive and oftentimes fatal. Occurrences such as these are usually the result of poor colony husbandry and management. Cross-infection is allowed to occur as a result of intermingling of species either by placing the animals directly in contact with each other or as a result of a more subtle mechanism involving the carrying of virus(es) by the personnel, their clothes, or instruments. Serological surveillance may be helpful in recognizing such episodes.

Examples of such crossings are, unfortunately, only too frequently encountered. V340, an adenovirus, was isolated in our laboratory from an imported African green monkey with a fatal pneumoenteritis (204). Further studies with this

agent found that occasionally it could be isolated from imported baboons but much more frequently from perinatal baboons in our colony (77). Since the African green monkeys were housed in the same building with experimental baboons, it was assumed that V340 was passing from the African green monkeys to the baboons. Serological studies have demonstrated that this is a false assumption. Baboons have V340 SN antibody in their sera immediately after capture in Africa. African green monkeys are essentially devoid of this antibody upon arrival at our laboratory. Within a very short period of time, approximately 25% of these African greens converted to seropositive. Such conversions have also been demonstrated by virus isolations. It is now felt that this virus is carried as a latent infection in adult baboons, and colony-born baboons reflect their susceptibility.

Examination of the serological data (Tables 4–17) suggests the likelihood that SA7, originally isolated from African green monkey kidney cell cultures, is also commonly infectious for baboons in the wild. SV15 and SV23, originally and frequently isolated from macaques, rarely occur in African primates until sometime after capture, when exposure to Asian animals or human vectors occurs. On several occasions these agents have been isolated from stool specimens collected from baboons in Africa (Kenya). These viruses are frequently found in Asian macaques, but no known contact occurred between these animals and the African baboons sampled. The source of the Asian viruses (SV15 and SV23) in African animals, therefore, is unknown.

As indicated above, reovirus types 1 (SV12, SA3) and 2 (SV59) have been frequently isolated from Old World primates. Serological data have shown that type 3 antibodies are very frequently found in a variety of nonhuman primates, but there are no published reports of a type 3 isolate having been made. Human and simian reovirus types are indistinguishable in the HI test with hyperimmune sera, but more serological testing is required to determine whether the simian isolates are identical with their human counterparts or if they constitute a unique group. In support of their uniqueness is the finding that primate sera may contain antibody for the human serotypes but not the simian. The converse is also true. Furthermore, simian reoviruses do not appear to be highly pathogenic for newborn mice as are the human strains. Only limited attempts have been made, however, to adapt the simian viruses to growth in mice.

The prototype foamy viruses have been isolated from a number of different genera of primates: *Macaca*, *Cercopithecus*, *Saimiri*, *Galago*, and *Pan*. Foamy virus contamination of baboon kidney cells also has been frequently encountered in our laboratory. The information currently available on these viruses makes it unlikely that they are myxoviruses, as previously classified. In some respects, they do not appear to be uniform in their properties. For example, not all of the foamy viruses respond in like manner to halogenated deoxyuridine ribosides (281); therefore, the status of their nucleic acid type remains in question. Clinical disease in simians has not been reported for these viruses. Possibilities for interspecies infection are unknown owing to limited studies on experimental infections. The presence of these viruses in primary cell cultures continues to be a nuisance, as there is no effective mechanism for control. Latent infection undoubtedly adds to the futility of any attempt to irradicate these viruses from a colony.

The herpesviruses are rather diversified in their host range (Table 2) and probably represent a high order of parasitism. Natural host reactions are generally mild and inapparent, contrasting with the extreme invasiveness which may be observed when a new host is invaded. In the natural host, the virus exists in the form of a latent infection for extended periods of time, but little is known regarding the pathogenesis of this group of agents after invasion of a new host animal. Whether all the members of this group are capable of being highly invasive is a moot point. SA8 has been associated with mild clinical disease when inoculated into the African green monkey, the species from which it was originally isolated (224). This virus has been isolated by Malherbe and Strickland-Cholmeley (227, 228) as well as in our laboratory (188) from apparently normal baboons. The spider monkey herpesvirus (SMV) was isolated from the brain of a monkey dying with an apparently generalized herpetic infection. Antibody to this virus has been reported in squirrel and capuchin monkeys, but the reservoir host or the effect of interspecies exchange by this virus has not been determined (158). Melendez and his collaborators (237, 240) have recovered a number of herpesviruses from New World monkeys. One virus, *H. saimiri*, isolated from a squirrel monkey has been shown to produce a reticulum cell lymphoma in the owl monkey and marmoset (240). Thus we are faced with a virus group that has the potential for producing not only a highly invasive acute infection but, in certain hosts, induces a disease which has all the characteristics of a neoplasia. The New World monkeys seem to be more susceptible to herpesvirus disease than Old World monkeys. The buccal lesions caused by B virus on rhesus monkeys seem to be the extreme clinical

disease observed in Asian and African monkeys naturally infected by herpesviruses. As just mentioned, SMV caused a fatal infection of a spider monkey, *H. tamarinus* has caused a number of deaths in marmosets and owl monkeys and, finally, *H. hominis* has been implicated as the cause of death in marmosets and owl monkeys. The reasons for this sensitivity to herpesvirus infections in New World monkeys, especially when the infecting agent is not in its natural host, are unknown but are basic to the understanding of latency and viral pathogenesis.

Less is known about the type B (Table 2) herpesviruses than the type A. These viruses have the characteristics of the cytomegaloviruses and as such have a tendency to produce latent infections with a pattern of cell persistence for extensive periods of time. Cytomegaloviruses have been recovered from African green monkey cell cultures and tissues on a number of occasions (29, 69, 223). In a study by Smith et al. (317), over 50% of kidney cell cultures derived from these animals carried cytomegalovirus as a latent infection.

Isolation of other viruses—poxviruses, Marburg, simian hemorrhagic fever—have been mentioned above as examples of "new" outbreaks. All these have the capacity of producing overwhelming and oftentimes fatal epidemics, evidently in species other than their natural reservoir. Quarantine of the animal may be useless unless a mechanism for detecting changes (serologic surveys, virus isolations) is instituted and maintained as a monitoring system. Keeping the animals in isolation and quarantine is effective only if laboratory personnel understand the problem and cooperate by limiting their contact and instituting a proper protective barrier (clothing, boots, masks) and self-restraint in moving from one group of animals to another. Vaccination is rather limited and effectively includes only yellow fever, poliomyelitis, and smallpox (for monkey pox).

There are many parameters in need of extensive study and development. Need for more vaccines is evident from the limited list of effective vaccines. Factors responsible for the increase in virulence that occurs when a virus passes from its reservoir host species to another are not understood. This becomes a major point of consideration when plans for breeding many of these animals are considered. The newborn represents an immunologically naive animal which is highly susceptible to a variety of infections by numerous indigenous parasites of the adult and exogenous populations. Thus, even when a colony is maintained under rigid precautions, an infectious agent may still be perpetuated in the host animals.

Experiences in this colony (SFRE) and that of others emphasize the continued shedding of viruses as determined by monitoring of the animals. Extreme care in interpretating data must be exerted, as the history and previous experiences of these animals are frequently vague and confused by numerous unknown or unreported contacts with other animals. Shedding of virus is not uniform and is probably influenced by numerous unknown factors. For example, the 5-month period after arrival of baboons from Africa is the time of highest virus recovery (186). This is attributed to the "stress" of travel and has been observed upon numerous occasions. Hull (157) reported on the incidence of virus isolations as determined by frequency of recovering simian viruses over different periods of time. For example, viruses recovered most often during 1955 to 1958 were (numbers in parentheses indicate frequency of isolations): SV4 (504), SV12 (173), SV28 (65), SV11 (44), SV15 (42), SV17 (41), SV5 (32), SV23 (25), B virus (20), others (5). In 1958 to 1962, the following were recovered: SV28 (15), SV23 (13), SV5 (7), SV17 (6), SV40 (5), SA1 (4), SV38 (3), SV32 (2), SV31 (2), other (1). Subsequent to 1958 to 1962, fewer rhesus monkeys were used, they were handled and housed differently, and, more importantly, the use of African green monkeys exceeded rhesus. The isolations for 1962 to 1967 were: SV5 and SA1 (most frequent), SV41 (12 isolations in 1963 only), and very infrequent recovery of SV5, SV16, SV17, SV18, SV23, SV26, SV40, and SA5.

Virus isolations in this laboratory indicate recovery of many of the recognized simian virus serotypes. Among the simian adenovirus prototypes most frequently isolated from baboons are SV15, SV23, SA7, and V340. Other viruses less frequently encountered are SV1, SV17, SV20, SV25, SV33, SV34, and AA153. Other classes of viruses represented among the identified isolates are the picornaviruses (SV6, SV19, A13), herpesviruses (SA8, *H. simplex*), and reoviruses (type 2). New agents are only infrequently encountered. Verification of this type of finding may be seen in the reports by Soike et al. (320–322) with the chimpanzee. These investigators, in recovering viruses from this animal, found that few of the isolates fell into a "new virus group"; most belonged to previously described virus groups. The chimpanzee isolates, in contrast to our findings with the baboon, show that a large number of the isolates undoubtedly result from contact with humans. Rogers et al. (281) found that isolates obtained from chimpanzee tissues maintained for extended periods of time were new but fell into recognized established virus families —adenoviruses, reoviruses, and foamy viruses.

The isolates described by Hsiung and her coworkers (149, 154) from captive monkeys (*M. mulatta, C. aethiops, Papio* sp.) are those that very frequently have been found in these species and probably typify contamination by one or another of the described sources.

VIRUS DISEASES AND EXPERIMENTAL INFECTIONS

Virus Diseases

A number of texts and monographs are available characterizing various diseases of nonhuman primates; the work of Ruch (283) is classic in this field as is that of Fiennes (82). These references will supply the reader with background and general information relative to simian diseases but, unfortunately, most of these reports are inadequate in developing a clear understanding regarding the actual problem of zoonoses and anthroponoses. The inadequacies are based not on the reports but on the failure of most investigators utilizing monkeys and apes to develop a program for defining infections and diseases of the very tools they are using for studies of human infections and diseases.

Only when the loss of these animals has been threatened or illness or death occurred among the human personnel has any attempt been made to explore the problem. Thus, Mattingly (231) discussed *Major Zoonoses of Primates* and described two virus diseases, B virus infection and infectious hepatitis; Hartley (122) listed three primate virus diseases—B, vervet monkey disease, and rabies; and Appleby et al. (9) described B virus. Trum and Routledge (340) mentioned "measles and poxes" but indicated that "they do not seem to be a colony problem." They described herpesviruses, especially *H. tamarinus*, as causing a serious problem and *H. simiae* as a serious zoonotic problem, but not for monkeys. Habermann et al. (115) listed the "important viral diseases in man and other animals" and included pseudorabies, variola (smallpox), rubeola, varicella (herpes zoster was listed separately), herpes simplex, Sabin B, giant cell pneumonia, yellow fever, louping ill, salivary gland disease, lymphocytic choriomeningitis, dengue, poliomyelitis, Western and Eastern equine encephalitis, and St. Louis encephalitis, as diseases to which monkeys are susceptible. In a previous report concerning diseases seen at necropsy of 708 rhesus and cynomolgus monkeys, Habermann and Williams (114) suggested that viral disease was associated with two cynomolgus monkeys as exemplified by "giant cell pneumonia with intranuclear and cytoplasmic inclusion bodies." Only vague association of viral disease occurring in 600 monkeys was made by Fairbrother and Hurst (81). Kennard (203) described 246 consecutive necropsies on monkeys without reference to a viral disease. Viral diseases of laboratory animals as described by Ditchfield (65) lists B virus infection and mentions monkeys as well as other animals as hosts of cytomegaloviruses. Only brief mention is made of viral problems associated with the breeding of macaques (341). Diseases of the marmoset (*T. nigricollis*) after 506 necropsies were not considered to be related to viruses, although "infections" were responsible for more than 50% of marmoset deaths during the first 7 days of arrival in the colony (255). Gengozian (95) lists only two viral agents to be of any consequence among marmosets—herpesvirus (*H. tamarinus*) and yellow fever virus. Vickers (345) lists herpesvirus (B virus), yellow fever, and Rift Valley fever as diseases of the African green and, probably, the patas monkeys. Diseases of the baboon were indicated as "minimal," with no mention made of specific viral infections. Of the marmosets, Vickers (345) described herpesvirus and pneumonia (respiratory disease), the latter as "bacterial" in etiology. *Herpesvirus simiae* was the only viral disease listed for macaques. A more realistic appraisal of the situation was offered by Eyestone (79) who indicated yellow fever, herpes B, monkey pox, rabies, infectious hepatitis, measles (rubeola), Kyasanur forest, green monkey disease (Marburg), and simian hemorrhagic disease as recent zoonoses associated with nonhuman primates. A similar and even more extensive listing was provided by Wedum and Kruse (248) as part of their assessment of risk of human infection in the microbiological laboratory. These investigators described 16 viruses that were excreted from monkeys via urine or feces. Some 20 viruses, including most of the above 16, were found to infect uninoculated control monkeys kept caged with or near the inoculated animals.

Detailed examination of these reports reveals a pattern that suggests a gradual increase in the occurrence of primate diseases as more and more monkeys and apes are employed. For example, three of the more important diseases (Marburg, simian hemorrhagic fever, and monkey pox) have been described within the last 5 years. Kyasanur Forest disease and infectious hepatitis have been recognized only a few years longer. Additional problems will develop as a result of current and probably future expanded use of these animals. Trum and Routledge (340) consider measles (rubeola) as inconsequential in monkey colonies. Levy and Mirkovic (*unpublished data*) described an epidemic of measles in a marmoset colony in which 326 animals died within a 5.5-month period. The mortality from the Marburg virus, both in

man and simians, and simian hemorrhagic fever in simians has been mentioned above. High mortality rates due to the herpesviruses in various nonreservoir hosts are also well established.

These findings suggest several potential problem areas. Perhaps most important is the recognition that increased usage of nonhuman primates, with the expanded employment of more exotic species, continues to threaten man and stabilized animal colonies by exposure to unknown and possibly highly lethal viruses. The serological evidence presented above and the fact that infection without disease is even more frequent tend to suggest that an immunological equilibrium has been established among the primates to many of the virus diseases. In other instances both man and his simian "relatives" are incidental victims of a natural process involving disease cycles usually with a vector—yellow fever, Kyasanur Forest, dengue, and other arbovirus infections. Introduction of a virus into a community of immunological susceptibles results in infection or disease, or both, depending upon many intrinsic and extrinsic factors. Thus, SV40 and other simian virus infections evidently have resulted in little more than antibody productions in man; Marburg virus has produced illness and many deaths. Rubeola in macaques resulted in virus localization in tissues with antibody development; in marmosets, however, there were numerous deaths.

As part of this problem, difficulties will develop in recognizing an isolate as the true etiological agent and distinguishing it from that of a simple passenger virus. This has been seen or suspected in a number of instances, such as reoviruses and adenoviruses from experimentally induced hepatitis animals. Latent infections, in contrast to infections due to rapidly replicating lytic agents, will undoubtedly be of concern to those investigators involved in studies with tumor viruses or viruses grouped under the heading of "slow, latent, and temperate viruses." Differentiation of virus isolates will require care and caution in the final interpretation. It is questionable, at this time, if one may state with any degree of finality, whether our methodological capability is sufficiently developed to distinguish between the infecting agent and those viruses that may be residing on or within the host cells. Current understanding of the exact relationship between the virus nucleic acid genome and host cell chromosomal material in latent infections is still not clear. Perhaps some adaptation of the procedures employed by the immunologist involved in the search for a clue to the virus relationship to cancer may offer an opportunity to understand latent infections as they pertain to all viruses. Do viruses involved in latent infections produce neoantigens or transplantation antigens not structurally related to the virion? Until we are able to obtain evidence of latent virus infection through their components, or virus-induced antigen, such an infection will remain undetected.

Experimental Infections

Monkeys and apes have undoubtedly been employed to examine practically every known disease of man or used in an attempt to determine the etiology of unknown human diseases. Most of these studies have been limited and dependent upon the availability of one or another primate species. Little has been done, until recently, to systematically utilize these animals for studies in depth of the pathogenesis of various viruses or establish nonhuman primate as an experimental model system.

Cornelius (55) refers to "animal models" as a "neglected medical resource" and indicates that "many diseases that occur spontaneously in animals with similar counterparts in man either have been only superficially studied or still remain to be discovered." An extensive listing is provided by him supplying the animal model, species of animal, and the human counterpart. Three viral diseases are mentioned: viral hepatitis (subhuman primates), experimental kuru (chimpanzee), and molluscum contagiosum (chimpanzee). Similarly, Jones (169) emphasizes the establishment of a need for experimental animals "with clearly defined and uniform characteristics for biomedical research." He also points out that "animal diseases of every category are known to occur in so many species that one wonders why they have been used so seldom as models of human disease." Model systems of virus diseases that are given are few in number: herpes ("simian primate") and one or two suspected human diseases. This thought is pursued by Frenkel (90) with mention of monkeys and apes for the study of poxviruses and myocarditis. Koprowski (210) also suggested that animal counterparts would offer a fruitful approach to a better understanding of human disease, but gave only yellow fever in marmosets as an example of such an approach.

It is evident that there is a dichotomy between thought and practical application regarding the use of nonhuman primates in experimental studies. Current indications are more in keeping with the concept that an animal more closely related phylogenetically to man than to other experimental animals employed heretofore may offer a quicker resolution to the understanding of human ills. Undoubtedly such studies will also expand our knowledge of illnesses of the experimental host.

TABLE 19. *Nonhuman primates used in contemporary comparative virus research*[a]

Nonhuman primate	Virus or disease	Reference
Chimpanzee Spider monkey	Kuru, Scrapie, Creutzfeldt-Jakob	92–94, 102, 103
Chimpanzee Rhesus (newborns, immatures) Cynomolgus (newborns, immatures) African green (immatures) Slow Loris, Barbary Ape (immatures) Spider Squirrel	Amyotrophic lateral sclerosis, Kuru, subacute inclusion body encephalitis	102, 360
Rhesus	Infectious mononucleosis	99, 168
Marmoset Owl	Malignant lymphoma	239
Baboon	Cat scratch disease	*Unpublished data*
Cebus	Reticulum cell sarcoma	240
African green (suckling)	Burkitt's lymphoma	76
Rhesus African green Cercopithecid Squirrel Baboon	Rubella	62, 113, 129, 191, 261, 267, 297, 311
Macaque Baboon Chimpanzee (newborns, African green juveniles, Marmoset adults) Other species	Cancer	58, 182, 240, 244, 341
Marmoset Chimpanzee Patas	Hepatitis	23, 60, 242

[a] See text for experimental usage of monkeys and apes for established viruses or their diseases.

Table 19 provides a listing of nonhuman primates currently involved in various experimental studies. A number of these were not considered as virus diseases until recently. Establishment of the viral etiology of kuru and attempts to determine the etiology of other subacute chronic and degenerative diseases of the central nervous system in chimpanzees has done much to develop this type of study (92–94, 102, 103). Attempts to develop model systems for establishing a viral etiology for cancer are partially responsible for use of many simians. The need for a model system for the study of congenital malformations of viral etiology, especially those due to rubella virus, has prompted the use of nonhuman primates. Much of the work done was limited by utilization of small numbers of animals and questionable virus inocula. The number of possible susceptible hosts was also restricted. Recently we (191; *unpublished data*) were able to produce clinical rubella disease in the baboon, and studies are currently in progress to ascertain whether this species may be suitable for studies of congenital malformations.

SUMMARY AND CONCLUSIONS

Current utilization of vast numbers of monkeys and apes in biomedical research has prompted a reevaluation of these animals. We are concerned primarily with their use as model systems for the study of disease and with the very practical aspect of their potential danger in the spread of viruses to man (zoonoses) and from man to them (an-

throponoses). The importance of virus spread within the different primate species must also be given careful consideration.

Review of the literature emphasizes that most investigators employing these animals in their research still lack understanding of the magnitude of this problem. Little recognition is given to the potential danger, even though B virus infection was described approximately 40 years ago, and a number of major outbreaks have occurred with human fatalities from this and other viruses carried by simians. Most laboratories make no provision to protect their personnel nor provide suitable quarters to minimize the problem. Very little is done to obtain the animals properly in order to maintain healthy stock and prevent the spread of viruses. Of the various guides and standards developed and published within the last 10 years relating to use of nonhuman primates in the laboratory, little consideration has been given to any viral disease other than that caused by *H. simiae*. Occasionally yellow fever and infectious hepatitis may be mentioned. Little cognizance has been given to the spread of viruses from "normal" animals. The inherent threat involved in the spreading of the normal flora of one species to another species is usually not considered. Similar thoughts were recently expressed by Hunt (163*a*). Public Health Service Publication no. 1024 (Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, 1968) provides information suggesting the need of special facilities for biological safety in infectious disease units. However, there is little indication that intermingling of species or introduction of "new" animals of similar species into a stabilized colony may have the same effect as working with experimentally infected animals.

These dangers from the use of nonhuman primates may be limited if consideration is given to the following (177–179, 181, 186–188): (i) Large numbers of monkeys and apes, many of them overtly shedding viruses or harboring latent infections, are now being imported from all over the world and brought into laboratories with no previous experience with these animals. (ii) Exposure of laboratory personnel and other animals to new and exotic agents occurs. (iii) The incoming animals are now also exposed to a new flora and fauna. (iv) The mechanics of shipping these animals results in a marked enhancement of virus shedding. (v) A number of severe outbreaks have occurred recently in the human and simian populations with high mortality and morbidity rates. (vi) Considerably more information is required on the pathogenesis, epidemiology (especially as relates to interrelationships between various animal species), latency, and so on of many infectious agents, especially the viruses. (vii) Better methods for capturing, handling, and shipping of nonhuman primates are required to minimize losses that occur during this new phase in the lives of these animals in captivity. This will provide a healthier animal and will do much to conserve an important natural world resource. (viii) Better laboratory support and closer supervision of all these animals in captivity must be developed.

Use of monkeys and apes as experimental model systems has been accomplished to a degree but usually in a haphazard fashion. Very little in the way of a scientifically compatible organized program has been developed to insure maximal and valid results from the use of these animals in the study of disease processes. In general, the possible influence or hazard of the animal's natural flora on the outcome of the experiment has not been considered. Apropos of this has been the use of several simian species (primarily chimpanzees and baboons) for use in transplant and in in cross-circulation studies with humans. Very little has been done to examine these donor animals for evidence of viral infections. A recent symposium (273) considered infectious hepatitis virus, molluscum contagiosum (67), Marburg virus, "Coxsackie BL-34," and simian herpesvirus (253).

If such experiments are to continue and, more importantly, to succeed, a better insight into comparative virology (as well as other agents) is urgently needed. In this regard, we echo the sentiments of Shope (306) about the lack of knowledge concerning the ecology or natural history of viruses. For a virus to exist, a mechanism for its survival is necessary. Matumoto (232) discussed some of these mechanisms for viruses that infect man and other warm-blooded animals. In comparing the virology of primates, the similar susceptibility of many nonhuman primates to man is evident, as measured by serological response. Limited data on monkeys and apes in nature indicate differences in exposure to the same viruses which are overcome as the two groups are brought together in closer contact. Representatives of every major virus group are found in most primates. In certain instances the antigenic differences between these various strains are marked; they may, however, be extremely close and at times indistinguishable. Certainly, infection of man or monkey with one of these viruses is followed by appearance of clinical disease that is also similar or identical in both species. It is interesting to speculate as to the actual differences between these viruses as they infect man or another primate. Undoubtedly distinct and specific viruses exist among all species of animals. Many may be the same, but only by virtue of their per-

petuation cycles do they assume certain antigenic components of the different host tissues which contribute to the serological differences detected.

ACKNOWLEDGMENTS

Studies in this laboratory were supported by Public Health Service grants AI05374, RR00278, RR00361, RR00451, and RR05519, contract 69-93, and by WHO grant Z2/181/27.

The able assistance of C. S. Kim, A. K. Eugster, J. J. Ratner, A. R. Rodriquez, G. V. Kalter, M. Benke, H. McClure, W. Graham, C. Montilla, B. Tunmer, H. Magill, H. Jefferies-Klitch, R. J. Helmke, and D. Thomas is gratefully appreciated.

The cooperation of Yerkes Regional Primate Center, Holloman Air Force Base (6571st Aeromedical Research Laboratory); School of Aerospace Medicine (Brooks Air Force Base, Tex.); Delta Regional Primate Center; Institute Merieux (Lyon, France); Gorgas Memorial Laboratory (Panama); National Institutes of Health, Bethesda, Md.; Auburn University (Ala.); San Diego (Calif.) Zoo (Institute for Comparative Biology); Albany Medical School (Albany, N.Y.); Victoria (Tex.) Zoo; University of Texas Dental School Research Institute (Houston); Presbyterian-St. Luke's Hospital (Chicago, Ill.); National Taiwan University (Taipei, Taiwan); Laboratory for Experimental Medicine and Surgery in Primates (New York); Japan Monkey Center (Aichi, Japan); New England Regional Primate Center (Southborough, Mass.); Animal Care Facility (University of California, San Francisco); Oregon Regional Primate Center (Beaverton); Center for Disease Control (Atlanta, Ga.); Naval Air Station (Tallahassee, Fla.); University of Florida, College of Medicine (Gainesville, Fla.); The Poliomyelitis Research Foundation (Johannesburg, South Africa); The Medical Research Laboratory (Kenya, Africa); San Antonio Zoo (San Antonio, Tex.); Dept. of Interior (Cincinnati, Ohio); and National Center for Primate Biology (Davis, Calif.) in supplying sera from monkeys and apes is also appreciated.

LITERATURE CITED

1. Aisenberg, M. S., and T. C. Grubb. 1943. Poliomyelitis induced by inoculation of tooth pulp cavities. J. Bacteriol. 46:311.
2. Allmond, B. W., J. E. Froeschle, and N. B. Guilloud. 1967. Paralytic poliomyelitis in large laboratory primates. Virologic investigation and report on the use of oral poliomyelitis virus (OPV) vaccine. Amer. J. Epidemiol. 85:229-239.
3. Amoss, H. L. 1928. Virus diseases of man as exemplified by poliomyelitis, p. 159-201. *In* T. M. Rivers (ed.), Filterable viruses. The Williams & Wilkins Co., Baltimore.
4. Amstey, M. S. 1969. Intra-amniotic inoculation of rubella virus. Amer. J. Obstet. Gynecol. 104:573-577.
5. Anderson, G. R., and J. T. Sgouris. 1966. The preparation of rabies immune globulin and use in monkeys following virus challenge, p. 319-332. *In* Int. Symp. Rabies. Karger, Basel/New York.
6. Anderson, J. F., and J. Goldberger. 1911. The period of infectivity of the blood in measles. J. Amer. Med. Ass. 57:113-114.
7. Anderson, J. F., and J. Goldberger. 1911. The infectivity of the secretion and the desquamating scales of measles. J. Amer. Med. Ass. 57:1612-1613.
8. Anderson, J. F., and J. Goldberger. 1911. Experimental measles in the monkey. Pub. Health. Rep. 26:847-848.
9. Appleby, E. C., O. Graham-Jones, and S. A. Keeble. 1963. Primate diseases infectious to man. Vet. Rec. 75:81-86.
10. Arita, I., and D. A. Henderson. 1969. Smallpox and monkeypox in nonhuman primates. Bull. W.H.O. 39:277-283.
11. Armstrong, C. 1939. The experimental transmission of poliomyelitis to the eastern cotton rat, *Sigmodon hispidus hispidus*. Pub. Health Rep. 54:1719-1721.
12. Armstrong, C., and R. D. Lillie. 1934. Experimental lymphocytic choriomeningitis of monkeys and mice produced by a virus encountered in studies of the 1933 St. Louis encephalitis epidemic. Pub. Health Rep. 49:1019-1027.
13. Armstrong, D., G. Henle, and W. Henle. 1966. Complement-fixation tests with cell lines derived from Burkitt's lymphoma and acute leukemias. J. Bacteriol. 91:1257-1262.
14. Armstrong, C., J. G. Wooley, and R. H. Onstott. 1936. Distribution of lymphocytic choriomeningitis virus in the organs of experimentally inoculated monkeys. Pub. Health Rep. 51:298-303.
15. Atoynatan, T., and G. D. Hsiung. 1969. Epidemiologic studies of latent virus infections in captive monkeys and baboons. II. Serologic evidence of myxovirus infections with special reference to SV5. Amer. J. Epidemiol. 89: 472-479.
16. Aulisio, C. G., D. C. Wong, and J. A. Morris. 1964. Neutralizing antibodies against simian viruses, SV5 and SV20 in human sera. Proc. Soc. Exp. Biol. Med. 117:6-11.
17. Aycock, W. L. 1940. The epidemiology of poliomyelitis, p. 555-580. *In* Virus and rickettsial diseases. Harvard School of Public Health, Symposium. Harvard University Press, Cambridge, Mass.
18. Aycock, W. L., and J. R. Kagan. 1927. Experimental immunization in poliomyelitis. J. Immunol. 14:85-99.
19. Aycock, W. L., and S. D. Kramer. 1930. Immunity to poliomyelitis in normal individuals in urban and rural communities as indicated by the neutralization test. J. Prev. Med. 4:189-200.
20. Back, N., J. L. Ambrus, and S. S. Kalter. 1965. The use of the primate in oncogenic virus studies, p. 421-429. *In* H. Vagtborg (ed.), The baboon in medical research. University of Texas Press, Austin.
21. Balfour, A. 1914. The wild monkey as a reservoir for the virus of yellow fever. Lancet 1:1176-1178.
22. Bang, J. 1942. Experiments with transfer of infectious mononucleosis to monkeys (*Macacus rhesus*)—with negative results. Acta Med. Scand. 111:291-302.
23. Bearcroft, W. G. C. 1963. Hepatitis in African monkeys. Nature (London) 197:806-807.
24. Bearcroft, W. G. C. 1964. Histologic studies on the liver of West African primates inoculated with infectious hepatitis. J. Pathol. Bacteriol. 88:511-519.
25. Bearcroft, W. G. C. 1969. Studies on the transmission of the agent of infectious hepatitis to patas monkeys. J. Med. Microbiol. 1:1-21.
26. Bearcroft, W. G. C., and M. F. Jamieson. 1958. An outbreak of subcutaneous tumors in rhesus monkeys. Nature (London) 182:195-196.
27. Berman, L. D., P. M. Coates, and P. J. Simons. 1967. Tumors and immunological response in rhesus monkeys born after *in utero* inoculation with rous sarcoma virus. J. Nat. Cancer Inst. 39:119-134.
28. Bhatt, P. N., C. D. Brandt, R. A. Weiss, J. P. Fox, and M. F. Shaffer. 1966. Viral infections of monkeys in their natural habitat in Southern India. II. Serological evidence of viral infection. Amer. J. Trop. Med. Hyg. 15:561-566.
29. Black, P. H., J. W. Hartley, and W. P. Rowe. 1963. Isolation of a cytomegalovirus from African green monkey. Proc. Soc. Exp. Biol. Med. 112:601-605.
30. Blacklow, N. R., M. D. Hoggan, and W. P. Rowe. 1968. Serologic evidence for human infection with adenovirus-associated virus. J. Nat. Cancer Inst. 40:319-328.
31. Blake, F. G., and J. D. Trask. 1921. Studies on measles. I. Susceptibility of monkeys to the virus of measles. J. Exp. Med. 33:385-412.
32. Blake, F. G., and J. D. Trask, Jr. 1921. Studies on measles. II. Symptomatology and pathology in monkeys experimentally infected. J. Exp. Med. 33:413-422.
33. Blaxall, F. R. 1923. La variole en angleterre pendant l'annee 1922 avec quelques notes sur des experiences faites sur'ce sujet. Bull. Acad. Med. Paris 89:146-158.
34. Bleyer, J. G. 1922. Ueber Auftreten von Variola unter Affen

der Genera Mycetes und Cebus bei Vordringen liver Pockenepidemie in Urivaldgebiete an den Nebenfliissen des Alto Uruguay in Südbrasilien. Muenchen Med. Wochenschr. 69:1009–1010.
35. Bloch, O., Jr. 1937. Specificity of lesion of experimental mumps. Amer. J. Pathol. 13:939–944.
36. Blumberg, B. S., H. J. Alter, and S. A. Visnich. 1965. A "new" antigen in leukemia sera. J. Amer. Med. Ass. 191: 541–546.
37. Blumberg, B. S., A. I. Sutnick, and W. T. London. 1968. Hepatitis and leukemia: their relation to Australia antigen. Bull. N.Y. Acad. Med. 44:1566–1586.
38. Boorman, J. P. T., and C. C. Draper. 1968. Isolations of arboviruses in the Lagos area of Nigeria and a survey of antibodies to them in man and animals. Trans. Roy. Soc. Trop. Med. Hyg. 62:269–277.
39. Boulger, L. R. 1966. Natural rabies in a laboratory monkey. Lancet 1:941–943.
40. Bras, G. 1922. The morbid anatomy of smallpox. Doc Med. Geogr. Trop. 4:303–351.
41. Burkitt, D. 1958. A sarcoma involving the jaws in African children. Brit. J. Surg. 46:218–223.
42. Burnet, F. M. 1940. Epidemiology of poliomyelitis with special reference to Victorian epidemic of 1937–38. Med. J. Aust. 1:325–336.
43. Burnet, F. M., A. V. Jackson, and E. G. Robertson. 1939. Poliomyelitis. 3. Use of *Macacus cynomolgus* as an experimental animal. Aust. J. Exp. Biol. Med. Sci. 17:375–391.
44. Burnet, F. M., D. Lush, and A. V. Jackson. 1939. The relationship of herpes and B viruses: immunological and epidemiological considerations. Aust. J. Exp. Biol. Med. Sci. 17:41–51.
45. Cabasso, V. J., W. A. Chappell, J. E. Avampato, and J. L. Bittle. 1967. Correlation of B virus and herpes simplex virus antibodies in human sera. J. Lab. Clin. Med. 70: 170–178.
46. Cabasso, V. J., and M. R. Stebbins. 1965. Study of spread of rubella virus from inoculated to uninoculated contact *Cercopithecus* monkeys. J. Lab. Clin. Med. 65:612–616.
47. Cabasso, V. J., M. R. Stebbins, S. Karelitz, C. P. Cerini, J. M. Ruegsegger, and M. Stillerman. 1967. Attenuation of rubella virus: studies in monkeys and man. J. Lab. Clin. Med. 70:429–441.
48. Casey, M. J., H. C. Turner, R. J. Huebner, P. S. Sarna and R. L. Miller. 1966. Complement-fixing antibodies in monkeys bearing tumors induced by rous sarcoma virus. Nature (London) 211:1417–1418.
49. Chanock, R., and L. Finberg. 1957. Recovery from infants with respiratory illness of virus related to chimpanzee coryza agent (CCA). II. Epidemiologic aspects of infection in infants and young children. Amer. J. Hyg. 66: 291–300.
50. Cho, C. T., C. R. Bolano, P. S. Kamitsuka, and H. A. Wenner. 1970. Methisazone and monkeypox virus: studies in cell cultures, chick embryos, mice and monkeys. Amer. J. Epidemiol. 92:137–144.
51. Chumakov, M. P., S. G. Dzagurov, M. Ya. Chumakov, V. I. Chernyshov, and M. N. Bardin. 1963. Studies on the effectiveness of quarantine for *Macaca rhesus* and green monkeys in relation to the prevention of SV40 spread, p. 194. (in Russian). *In* Poliomyelit i drugie enterovirusvye infektsu, Moscow.
52. Chumakova, M. Ya, M. P. Chumakov, L. B. Elbert, G. I. Augustinovich, N. M. Ralph, M. K. Voroshilova, G. P. Taranova, and V. O. Tapupere. 1963. Recovery of antibody to monkey virus 40 in human sera. Serological evidence on infection from monkeys and kidney cultures (in Russian). Vop. Virus. 8:457–460.
53. Clarkson, M. J., S. Thorpe, and K. McCarthy. 1967. A virus disease of captive monkeys (*Cercopithecus aethiops*) caused by a new herpesvirus. Arch. Gesamte Virusforsch. 22:219–234.
54. Cole, R., and A. G. Kuttner. 1925. The problem of the etiology of herpes zoster. J. Exp. Med. 42:799–820.
55. Cornelius, C. 1970. Animal models—a neglected medical resource. N. Engl. J. Med. 281:934–944.
56. Cowdry, E. V., and G. H. Scott. 1935. Nuclear inclusions suggestive of virus action in the salivary glands of the monkey, *Cebus fatuellus*. Amer. J. Pathol. 11:647–658.
57. Danes, L., and K. Blazek. 1966. Experimental infection of monkeys of the species Mac. rhesus with poxvirus variolae and P. officinale after preimmunization with non-infectious antigen. J. Hyg. Epidemiol. (Praha) 10:109–114.
58. Deinhardt, F. 1967. Rous sarcoma virus—induced neoplasms in new world nonhuman primates, p. 183–197. *In* M. Pollard (ed.), Perspectives in virology, vol. 5. Academic Press Inc., New York.
59. Deinhardt, F. 1969. Viral oncogenesis and results of inoculation of normal and transformed cells into nonhuman primates. Nat. Cancer Inst. Monogr. no. 29, p. 327–331.
60. Deinhardt, F. 1970. Hepatitis in subhuman primates and the hazards to man, p. 55–63. *In* H. Balner and W. I. B. Beveridge (ed.), Infections and immunosuppression in subhuman primates. Munksgaard, Copenhagen.
61. Deinhardt, F., A. W. Holmes, J. Devine, and J. Deinhardt. 1967. Marmosets as laboratory animals. IV. The microbiology of laboratory kept marmosets. Lab. Anim. Care 17:48–70.
62. Delahunt, C. S., and N. Rieger. 1967. Rubella-induced embryopathies in monkeys. Amer. J. Obstet. Gynecol. 99:580–588.
63. Dick, E. C. 1968. Experimental infection of chimpanzees with human rhinovirus types 14 and 43. Proc. Soc. Exp. Biol. Med. 127:1079–1081.
64. Dick, E. C., and C. R. Dick. 1968. A subclinical outbreak of human rhinovirus infection in chimpanzees. Amer. J. Epidemiol. 88:267–272.
65. Ditchfield, W. J. B. 1968. Viral diseases of laboratory animals. Can. Med. Ass. J. 98:903–907.
66. Dochez, A. R., G. S. Shibley, and K. C. Mills. 1930. Studies on the common cold. IV. Experimental transmission of the common cold to anthropoid apes and human beings by means of a filtrable agent. J. Exp. Med. 52:701–716.
67. Douglas, J. D. 1970. Suitability and availability of chimpanzees as organ donors for man. Transplant. Proc. 2:539–541.
68. Draper, C. C., and G. D. Laurence. 1969. Susceptibility of *Erythrocebus patas* monkeys to rubella virus. J. Med. Microbiol. 2:249–252.
69. Dreesman, G. R., and M. Benyesh-Melnick. 1967. Spectrum of human cytomegalovirus complement-fixing antigens. J. Immunol. 99:1106–1114.
70. Eckstein, A. 1933. Klinische und experimentelle Untersuchungen zur Prage der Varicellenencephalitis. Z. Gesamte Neurol. Psychiat. 149:176–190.
71. Eddy, B. E., G. S. Borman, W. Berkeley, and R. D. Young. 1961. Tumors induced in hamsters by injection of rhesus monkey kidney cell extracts. Proc. Soc. Exp. Biol. Med. 107:191–197.
72. Elford, W. J., and I. A. Galloway. 1933. Size of virus of louping-ill of sheep by method of ultrafiltration analysis. J. Pathol. Bacteriol. 37:381–392.
73. Enders, J. F., and T. C. Peebles. 1954. Propagation in tissue cultures of cytopathogenic agent from patients with measles. Proc. Soc. Exp. Biol. Med. 86:277–289.
74. Enders, J. F., T. H. Weller, and F. C. Robbins. 1949. Cultivation of lansing strain of poliomyelitis virus in cultures of various human embryonic tissue. Science 109:85–87.
75. Endo, M., T. Kamimura, N. Kusano, K. Kawai, Y. Aoyama, Y. Tajima, K. Suzuki, and S. Kotera. 1960. Etude du virus B au Japan. II. Le premier isolement du virus B au Japan. Jap. J. Exp. Med. 30:385–392.
76. Epstein, M. A., and Y. M. Barr. 1964. Cultivation *in vitro* of human lymphoblasts from Burkitt's malignant lymphoma. Lancet 1:252–253.

77. Eugster, A. K., S. S. Kalter, C. S. Kim, and M. E. Pinkerton. 1969. Isolation of adenoviruses from baboons (*Papio* sp.) with respiratory and enteric infections. Arch. Gesamte Virusforsch. 26:260–270.
78. Evans, A. S. 1954. Attempts to transmit the virus of human hepatitis to primates other than man, p. 58–66. Symposium on the laboratory preparation and detection of the agent of hepatitis. Nat. Acad. Sci. Publ. no. 322, Washington, D.C.
79. Eystone, W. H. 1968. Recent developments of zoonoses associated with nonhuman primates. J. Amer. Vet. Med. Ass. 153:1767–1770.
80. Faber, H. K., R. J. Silverberg, and L. Dong. 1944. Poliomyelitis in cynomolgus monkey; infection by inhalation of droplet nuclei and nasopharyngeal portal of entry, with note on this mode of infection in rhesus. J. Exp. Med. 80:39–57.
81. Fairbrother, R. W., and E. W. Hurst. 1932. Spontaneous diseases observed in 600 monkeys. J. Pathol. Bacteriol. 35:867–873.
82. Fiennes, R. 1967. Zoonoses of primates. Cornell Univ. Press, Ithaca, N.Y.
83. Findlay, G. M. 1932. Rift Valley fever or enzootic hepatitis. Trans. Roy. Soc. Trop. Med. Hyg. 25:229–265.
84. Findley, G. M., and R. D. Mackenzie. 1937. Transmission of fowl pests to ferrets. Brit. J. Exp. Pathol. 18:146–155.
85. Findley, G. M., and R. D. Mackenzie. 1937. Fowlpest: susceptibility of monkeys, hedgehogs and other animals. Brit. J. Exp. Pathol. 18:258–264.
86. Flexner, S., and P. A. Lewis. 1910. Experimental epidemic poliomyelitis in monkeys. J. Exp. Med. 12:227–255.
87. Fox, J. P., E. H. Lennette, C. Manso, and J. R. Sousa-Agniar. 1942. Encephalitis in man following vaccination with 17D yellow fever virus. Amer. J. Hyg. 36:117–142.
88. Fox, J. P., and H. A. Penna. 1943. Behavior of 17D yellow fever virus in rhesus monkeys. Relation to substrain, dose and neural or extraneural inoculation. Amer. J. Hyg. 38:152–172.
89. Fraumeni, J. F., Jr., F. Ederer, and R. W. Miller. 1963. An evaluation of the carcinogenicity of simian virus 40 in man. J. Amer. Med. Ass. 185:713–718.
90. Frenkel, J. K. 1969. Models for infectious diseases. Fed. Proc. 28:179–190.
91. Fuentes-Marins, R. A., A. R. Rodriguez, S. S. Kalter, A. Hellman, and R. A. Crandell. 1963. The isolation of enteroviruses from the "normal" baboon (*Papio doguera*). J. Bacteriol. 85:1045–1050.
92. Gajdusek, D. C., and C. J. Gibbs, Jr. 1968. Slow, latent and temperate virus infections of the central nervous system. *In* Infections of the nervous system. Res. Pub. A.R.N.M.D. 44:254–280.
93. Gajdusek, D. C., C. J. Gibbs, and M. Alpers. 1966. Experimental transmission of a kuru-like syndrome to chimpanzees. Nature (London) 209:794–796.
94. Gajdusek, D. C., C. J. Gibbs, D. M. Asher, and E. Davis. 1968. Transmission of experimental kuru to the spider monkey (*Ateles geoffreyi*). Science 162:693–694.
95. Gengozian, N. 1969. Marmosets: their potential in experimental medicine. Ann. N.Y. Acad. Sci. 162:336–362.
96. George S., and R. A. Feldman. 1969. Reovirus antibodies in animals in India. Ind. J. Med. Res. 57:2001–2006.
97. Gerber, P. 1967. Patterns of antibodies to SV40 in children following the last booster with inactivated poliomyelitis vaccines. Proc. Soc. Exp. Biol. Med. 125:1284–1287.
98. Gerber, P., and S. M. Birch. 1967. Complement-fixing antibodies in sera of human and nonhuman primates to viral antigens derived from Burkitt's lymphoma cells. Proc. Nat. Acad. Sci. U.S.A. 58:478–484.
99. Gerber, P., J. W. Branch, and E. N. Rosenblum. 1969. Attempts to transmit infectious mononucleosis to rhesus monkeys and marmosets and to isolate herpes-like virus. Proc. Soc. Exp. Biol. Med. 130:14–19.
100. Gerber, P., D. Hamre, R. A. Moy, and E. N. Rosenblum. 1968. Infectious mononucleosis: complement-fixing antibodies to herpes-like virus associated with Burkitt lymphoma. Science 161:173–175.
101. Gerber, P., and E. N. Rosenblum. 1968. The incidence of complement-fixing antibodies to herpes simplex, and herpes-like viruses in man and rhesus monkeys. Proc. Soc. Exp. Biol. Med. 128:541–546.
102. Gibbs, C. J., Jr. 1967. Search for infectious etiology in chronic and subacute degenerative diseases of the central nervous system. Curr. Top. Microbiol. 40:44–58.
103. Gibbs, C. J., D. C. Gajdusek, D. M. Asher, M. P. Alpers, E. Beck, P. M. Daniel, and W. B. Matthews. 1968. Creutzfeldt-Jakob disease (spongiform encephalopathy): transmission to the chimpanzee. Science 161:388–389.
104. Gispen, R., J. D. Verlinde, and P. Zwart. 1967. Histopathological and virological studies on monkeypox. Arch. Gesamte Virusforsch. 21:205–216.
105. Goldberger, J., and J. F. Anderson. 1911. An experimental demonstration of the presence of the virus of measles in the mixed buccal and nasal secretions. J. Amer. Med. Ass. 57:476–478.
106. Goldman, K. 1935. Spontaninfektion spinalar Kinderlahmung der Affen. Berlin. Tieraerztl. Wochenschr. 51: 497–499.
107. Goodwin, W. J. 1970. Current use of nonhuman primates in biomedical research. Lab. Anim. Care 20:329–332.
108. Gordan, M. H. 1914. Rep. Loc. Govt. Bd. New Ser. no. 96.
109. Gordan, M. H. 1925. Studies of the viruses of vaccinia and variola. Spec. Rep. Ser. Med. Res. Council, London, no. 98.
110. Gralla, E. J., S. J. Ciecura, and C. S. Delahunt. 1966. Extended B-virus antibody determinations in a closed monkey colony. Lab. Anim. Care 16:510–514.
111. Grossman, L. H., and S. D. Kramer. 1936. Attempts to infect the common marmoset monkey with the virus of poliomyelitis. Proc. Soc. Exp. Biol. Med. 35:345–347.
112. Haas, R., G. Maass, J. Muller, and W. Oehlert. 1968. Experimentelle Infektionen von *Cercopithecus aethiops* mit dem Erreger des Frankfurt-Marburg-Syndroms (FMS). Z. Med. Mikrobiol. Immunol. 154:210–220.
113. Habel, K. 1942. Transmission of rubella to *Macacus mulatta* monkeys. Pub. Health Rep. 57:1126–1139.
114. Habermann, R. T., and F. P. Williams. 1957. Diseases seen at necropsy of 708 *Macaca mulatta* (rhesus monkeys) and *Macaca philippinesis* (cynomolgus monkey). Amer. J. Vet. Res. 18:419–426.
115. Habermann, R. T., F. P. Williams, G. L. Fite. 1960. Inclusion bodies associated with viral diseases of man and other animals. J. Amer. Vet. Med. Ass. 137:161–176.
116. Haddow, A. J. 1952. A review of the results of yellow fever protection test on the sera of primates from Kenya (*Papio doguera furax, P. doguera ibeanus, P. doguera neumanni*). Ann. Trop. Med. Parasitol. 46:135–143.
117. Haddow, A. J., K. C. Smithburn, A. F. Mahaffy, and J. C. Burgher. 1947. Monkeys in relation to yellow fever in Bwamba Country, Uganda. (*Papio doguera tessellatus*). Trans. Roy. Soc. Trop. Med. Hyg. 40:677–700.
118. Hahon, N. 1961. Smallpox and related poxvirus infections in the simian host. Bacteriol. Rev. 25:459–476.
119. Halberstaedter, L., and S. von Prowazek. 1907. Über Zelleinschlüsse Parasitärer Natur beim Trachom. Arch. Gesundheitsamte. 26:44–47.
120. Hampar, B., D. A. Stevens, L. M. Martos, D. V. Ablashi, M. A. K. Burroughs, and G. A. Wells. 1969. Correlation between the neutralizing activity of human serum against herpes simplex virus and a simian herpesvirus (SA8). J. Immunol. 102:397–403.
121. Harrison, V. R., J. D. Marshall, and N. B. Guilloud. 1967. The presence of antibody to chikungunya and other serologically related viruses in the sera of subhuman

primate imports to the United States. J. Immunol. 98:979–981.
122. Hartley, E. G. 1968. Primate diseases. Vet. Rec. 83:6–7.
123. Heath, R. B., I. El Falaky, and J. E. Stark, R. H. Herbst-Laier, and N. M. Larin. 1966. Induced upper respiratory infection in the vervet monkey: a model of acute viral respiratory disease in man. Brit. J. Exp. Pathol. 47:93–98.
124. Heberling, R. L., and F. S. Cheever. 1960. Enteric viruses of monkeys. Ann. N.Y. Acad. Sci. 85:942–950.
125. Heberling, R. L., and F. S. Cheever. 1964. Some characteristics of the simian enteroviruses. Amer. J. Epidemiol. 81: 106–123.
126. Heberling, R. L., and F. S. Cheever. 1966. A longitudinal study of simian enterovirus excretion. Amer. J. Epidemiol. 83:470–480.
127. Heberling, R. L., and S. S. Kalter. 1970. Persistence and spread of influenza virus (A2/Hong Kong) in normal and poly I.C. treated baboons (*Papio cynocephalus*). Proc. Soc. Exp. Biol. Med. 135:717–723.
128. Heberling, R. L., and S. S. Kalter. 1970. Induction, course and transmissibility of monkeypox disease in the baboon (*Papio cynocephalus*). Xth Int. Congr. Microbiol. Mexico City, Mexico.
129. Heggie, A. D., and F. C. Robbins. 1963. Experimental rubella in rhesus monkeys. Proc. Soc. Exp. Biol. Med. 114:750–754.
130. Helmke, R. J., R. L. Heberling, and S. S. Kalter. 1970. Technique for viral neutralization antibody surveys in primary microcultures. Appl. Microbiol. 20:986–988.
131. Helwig, F. C., and E. C. H. Schmidt. 1945. A filter-passing agent producing interstitial myocarditis in anthropoid apes and small animals. Science 102:31–33.
132. Henle, G., and W. Henle. 1966. Immunofluorescence in cells derived from Burkitt's lymphoma. J. Bacteriol. 91:1248–1256.
133. Henle, G., W. Henle, and V. Diehl. 1968. Relation of Burkitt's tumor-associated herpestype virus to infectious mononucleosis. Proc. Nat. Acad. Sci. U.S.A. 59:94–101.
134. Hilleman, M. R., and J. H. Werner. 1954. Recovery of new agent from patients with acute respiratory illness. Proc. Soc. Exp. Biol. Med. 85:183–188.
135. Hillis, W. D. 1961. An outbreak of infectious hepatitis among chimpanzee handlers at a United States Air Force base. Amer. J. Hyg. 73:316–328.
136. Hindle, E. 1929. Filtrable viruses. Proc. Roy. Soc. Med. 22:823–826.
137. Hirschman, R. S., R. N. Shulman, L. F. Barker, and K. O. Smith. 1969. Virus-like particles in sera of patients with infectious and serum hepatitis. J. Amer. Med. Ass. 208: 1667–1670.
138. Hoffert, W., M. E. Bates, and F. S. Cheever. 1958. Study of enteric viruses of simian origin. Amer. J. Hyg. 68:15–30.
139. Holmes, A. W., R. G. Caldwell, R. E. Dedmon, and F. Deinhardt. 1964. Isolation and characterization of a new herpes virus. J. Immunol. 92:602–610.
140. Holmes, A. W., J. Devine, E. Nowakowski, and F. Deinhardt. 1966. The epidemiology of a herpes virus infection of New World monkeys. J. Immunol. 96:668–671.
141. Horstmann, D. M. 1969. Discussion paper: the use of primates in experimental viral infections—rubella and the rubella syndrome. Ann. N.Y. Acad. Sci. 162:594–597.
142. Howe, H. A., and D. Bodian. 1940. Portals of entry of poliomyelitis virus in the chimpanzee. Proc. Soc. Exp. Biol. Med. 43:718–721.
143. Howe, H. A., and D. Bodian. 1941. Poliomyelitis in the chimpanzee: a clinical-pathological study. Bull. Johns Hopkins Hosp. 69:149–181.
144. Howe, H. A., and D. Bodian. 1942. A note on the penetration of poliomyelitis virus from the gastrointestinal tract in the chimpanzee. J. Pediat. 21:713–716.
145. Howe, H. A., and D. Bodian. 1944. Poliomyelitis by accidental contagion in the chimpanzee. J. Exp. Med. 80: 383–390.
146. Howe, H. A., and D. Bodian. 1945. Passive immunity to poliomyelitis in the chimpanzee. J. Exp. Med. 81:247–254.
147. Hsiung, G. D. 1968. Latent virus infections in primate tissues with special reference to simian viruses. Bacteriol. Rev. 32:185–205.
148. Hsiung, G. D. 1969. Recent advances in the study of simian viruses. Ann. N.Y. Acad. Sci. 162:483–498.
149. Hsiung, G. D., and T. Atoynatan. 1966. Incidence of naturally acquired virus infections of captive monkeys. Amer. J. Epidemiol. 83:38–47.
150. Hsiung, G. D., T. Atoynatan, and C. W. Lee. 1969. Epidemiologic studies of latent virus infections in captive monkeys and baboons. I. Overall plans and virus isolations with special reference to SV40 and foamy viruses. Amer. J. Epidemiol. 89:464–471.
151. Hsiung, G. D., R. W. Chang, R. R. Cuadrado, and P. Isacson. 1965. Studies of parainfluenza viruses. III. Antibody responses of different animal species after immunization. J. Immunol. 94:67–73.
152. Hsiung, G. D., and W. H. Gaylord. 1961. The vacuolating virus of monkeys. I. Isolation, growth characteristics and inclusion body formation. J. Exp. Med. 114:975–986.
153. Hsiung, G. D., P. Isacson, and R. W. McCollum. 1962. Studies of a myxovirus isolated from human blood. I. Isolation and properties. J. Immunol. 88:284–290.
154. Hsiung, G. D., and J. L. Melnick. 1958. Orphan viruses of man and animals. Ann. N.Y. Acad. Sci. 70:342–360.
155. Huang, C. H. 1943. Further studies on the titration and neutralization of the western strain of equine encephalomyelitis virus in tissue culture. J. Exp. Med. 78:111–126.
156. Hull, R. N. 1968. The simian viruses. Virol. Monogr. 2:1–66. Springer-Verlag, New York.
157. Hull, R. N. 1969. Viral flora of primate tissues—discussion. Nat. Cancer Inst. Monogr. no. 29, p. 173–175.
158. Hull, R. N. 1969. The significance of simian viruses to the monkey colony and the laboratory investigator. Ann. N.Y. Acad. Sci. 162:472–482.
159. Hull, R. N., and J. R. Minner. 1957. New viral agents recovered from tissue cultures of monkey kidney cells. II. Problems of isolation and identification. Ann. N.Y. Acad. Sci. 67:413–423.
160. Hull, R. N., J. R. Minner, and C. C. Mascoli. 1958. New viral agents recovered from tissue cultures of monkey kidney cells. III. Recovery of additional agents both in cultures of monkey tissues and directly from tissues and excreta. Amer. J. Hyg. 68:31–44.
161. Hull, R. N., J. R. Minner, and J. W. Smith. 1956. New viral agents recovered from tissue culture of monkey kidney cells. I. Origin and properties of cytopathogenic agents SV1, SV2, SV4, SV5, SV6, SV11, SV12 and SV15. Amer. J. Hyg. 63:204–215.
162. Hull, R. N., and J. C. Nash. 1960. Immunization against B virus infection. I. Preparation of an experimental vaccine. Amer. J. Hyg. 71:15–28.
163. Hull, R. N., F. B. Peck, Jr., T. G. Ward, and J. C. Nash. 1962. Immunization against B virus infection. II. Further laboratory and clinical studies with an experimental vaccine. Amer. J. Hyg. 76:239–251.
163*a*. Hunt, R. D. 1970. Letter to the editor. Lab. Anim. Care 20:1007–1008.
164. Hurst, E. W. 1931. The transmission of "louping-ill" to the mouse and the monkey: histology of the experimental disease. J. Comp. Pathol. Ther. 44:231–245.
165. Hurst, E. W. 1936. Studies on pseudorabies (infectious bulbar paralysis, mad itch). III. The disease in rhesus monkey, *Macaca mulatta*. J. Exp. Med. 63:449–463.
166. Johnson, C. D., and E. W. Goodpasture. 1936. Experimental immunity to virus of mumps in monkeys. Amer. J. Hyg. 23:329–339.
167. Johnston, P. B. 1961. A second immunologic type of simian

foamy virus: monkey throat infections and unmasking by both types. J. Infec. Dis. 109:1–9.
168. Joncas, J., G. Lussier, and V. Pavilanis. 1966. Studies on infectious mononucleosis. II. Attempts at experimental transmission to monkeys. Can. Med. Ass. J. 95:151–154.
169. Jones, T. C. 1969. Mammalian and avian models of disease in man. Fed. Proc. 28:162–169.
170. Jungeblut, C. W., and E. T. Engle. 1932. On the property of certain normal animal sera to neutralize the virus of poliomyelitis. Proc. Soc. Exp. Biol. Med. 29:879–883.
171. Kafuko, G. W., B. E. Henderson, M. C. Williams, and R. E. Kissling. 1970. Investigations in Uganda relating to the Marburg agent, p. 45–48. *In* H. Balner and W. I. B. Beveridge (ed.), Infections and immunosuppression in subhuman primates. Munksgaard, Copenhagen.
172. Kalter, S. S. 1960. Animal "orphan" viruses. Bull. W.H.O. 22:319–337.
173. Kalter, S. S. 1963. Procedures for routine laboratory diagnosis of virus and rickettsial diseases. Burgess Publishing Co., Minneapolis.
174. Kalter, S. S. 1964. Enteroviruses in animals other than man, p. 126–159. *In* Institute on occupational diseases acquired from animals. Univ. of Michigan School of Public Health, Ann Arbor.
175. Kalter, S. S. 1965. Virus studies on the normal baboon, p. 407–420. *In* H. Vagtborg (ed.), The baboon in medical research. Univ. of Texas Press, Austin.
176. Kalter, S. S. 1968. Antibodies in primates to human and simian viruses—a comparative study. Bibl. Haematol. 31:338–342.
177. Kalter, S. S. 1969. Virus diseases of nonhuman primates, p. 86–99. Pan Amer. Health Organ. Sci. Publ. no. 182.
178. Kalter, S. S. 1969. Nonhuman primates in viral research. Ann. N.Y. Acad. Sci. 162:499–528.
179. Kalter, S. S. 1971. Virological study on nonhuman primates, p. 481–527. *In* Proceedings defining the laboratory animal in the search for health. Proc. Nat. Acad. Sci. U.S.A., Washington, D.C.
180. Kalter, S. S. 1971. A serological survey of primate sera to the Marburg virus, p. 177–187. *In* G. A. Martini and R. Siegert (ed.), Proc. Symp. Marburg virus disease. Springer-Verlag, Berlin.
181. Kalter, S. S. Serologic surveys. *In* R. N. Fiennes (ed.), Pathology of primates. S. Karger, Basel, *in press*.
182. Kalter, S. S., A. K. Eugster, T. E. Vice, C. S. Kim, and I. A. Ratner. 1968. Rous sarcoma in baboons: development of tumour in an uninoculated animal treated with cortisone. Nature (London) 218:884.
183. Kalter, S. S., R. Fuentes-Marins, R. A. Crandell, A. R. Rodriquez, and A. Hellman. 1964. Virus complement-fixation and neutralization studies on sera from the normal baboon (*Papio doguera*). J. Bacteriol. 87:744–746.
184. Kalter, S. S., and N. B. Guilloud. 1970. Chimpanzee viruses, p. 361–389. *In* G. H. Bourne (ed.), The chimpanzee, vol. 2. S. Karger, Basel.
185. Kalter, S. S., and H. Jeffries-Klitch. 1969. Yellow fever vaccination of primates. Amer. J. Trop. Med. Hyg. 18: 466–469.
186. Kalter, S. S., and R. L. Heberling. 1968. Viral flora of tissue sources—simian and human. Nat. Cancer Inst. Monogr. no. 29, p. 149–160.
187. Kalter, S. S., and R. L. Heberling. 1969. The study of simian viruses. W.H.O. Chron. 23:112–117.
188. Kalter, S. S., and R. L. Heberling. 1970. Serology of latent virus infections, p. 121–137. *In* H. Balner and W. I. B. Beveridge (ed.), Infections and immunosuppression in subhuman primates. Munksgaard, Copenhagen.
189. Kalter, S. S., and R. L. Heberling. 1971. Reovirus antibody in primates. Amer. J. Epidemiol. 93:403–412.
190. Kalter, S. S., and R. L. Heberling. 1971. Comparative virology of primates. *In* J. Moor-Jankowski and E. I. Goldsmith (ed.), Proc. 2nd Conf. Exp. Med. Surg. Primates. S. Karger, Basel., *in press*.
191. Kalter, S. S., and R. L. Heberling. 1971. Rubella infection of baboons (*Papio cynocephalus*).
192. Kalter, S. S., R. L. Heberling, A. R. Rodriguez, and R. J. Helmke. 1971. Virus excretion from captive newborn baboons (*Papio cynocephalus*). Proc. 3rd Inter. Congr. Primatology. S. Karger, Basel., *in press*.
193. Kalter, S. S., R. L. Heberling, T. E. Vice, F. S. Lief, and A. R. Rodriquez. 1969. Influenza (A2/Hong Kong/68) in the baboon (*Papio* sp.). Proc. Soc. Exp. Biol. Med. 132:357–361.
194. Kalter, S. S., R. E. Kuntz, Y. Al-Doory, and A. Katzberg. 1966. Collection of biomedical study materials from baboons in East Africa: preliminary report. Lab. Anim. Care 16:161–177.
195. Kalter, S. S., R. E. Kuntz, B. J. Myers, A. K. Eugster, A. R. Rodriguez, M. Benke, and G. V. Kalter. 1968. The collection of biomedical specimens from baboons (*Papio* sp.) in Kenya, 1966. Primates 9:123–139.
196. Kalter, S. S., J. J. Ratner, and R. L. Heberling. 1969. Antibodies in primates to the Marburg virus. Proc. Soc. Exp. Biol. Med. 130:10–12.
197. Kalter, S. S., J. Ratner, G. V. Kalter, A. R. Rodriquez, and C. S. Kim. 1967. A survey of primate sera for antibodies to viruses of human and simian origin. Amer. J. Epidemiol. 86:552–568.
198. Kalter, S. S., J. J. Ratner, A. R. Rodriguez, R. L. Heberling, and N. B. Guillloud. 1969. Antibodies to human and simian viruses in the gorilla (*Gorilla gorilla*). Lab. Anim. Care 19:63–66.
199. Kalter, S. S., J. J. Ratner, A. R. Rodriquez, and G. V. Kalter. 1967. Microbiological parameters of the baboon (*Papio* sp.): virology, p. 757–773. *In* H. Vagtborg (ed.), The baboon in medical research, vol. 2. Univ. of Texas Press, Austin.
200. Kalter, S. S., T. E. Vice, C. S. Kim, and I. A. Ratner. 1968. Rous sarcoma in baboons: development of tumor in uninoculated animal treated with cortisone. Nature (London) 218:884.
201. Kamitsuka, P. S., T. Y. Lou, A. Fabiyi, and H. A. Wenner. 1965. Preparation and standardization of coxsackievirus reference antisera. I. For twenty-four group A viruses. Amer. J. Epidemiol. 81:283–306.
202. Keeble, S. A., G. T. Christofinis, and W. Wood. 1958. Natural virus-B infection in rhesus monkeys. J. Pathol. Bacteriol. 76:189–199.
203. Kennard, M. A. 1941. Abnormal findings in 246 consecutive autopsies on monkeys. Yale J. Biol. Med. 13:701–712.
204. Kim, C. S., E. A. Sueltenfuss, and S. S. Kalter. 1967. Isolation and characterization of simian adenoviruses isolated in association with an outbreak of pneumoenteritis in vervet monkeys (*Cercopithecus aethiops*). J. Infec. Dis. 117:292–300.
205. Kissling, R. E., R. Q. Robinson, F. A. Murphy, and S. G. Whitfield. 1968. Agent of disease contracted from green monkeys. Science 160:888–890.
206. Kling, C., C. Levaditi, and G. Hornus. 1934. Comparison entre les divers modes de contamination du singe par le virus poliomyelitique (voies digestive et naso-pharynge). Bull. Acad. Med. Paris 111:709–716.
207. Kling, C., C. Levaditi, and L. Lepine. 1929. Le penetration du virus poliomyelitique a travers la muqueuse du tube digestif chez le singe et sa conservation dans l'eau. Bull. Acad. Nat. Med. Paris 102:158–159.
208. Kolmer, J. A. 1934. Successful method for vaccination against acute anterior poliomyelitis; preliminary report. Amer. J. Med. Sci. 188:510–514.
209. Kolmer, J. A., and A. M. Rule. 1934. Concerning vaccination of monkeys against acute anterior poliomyelitis with special reference to oral immunization. J. Immunol. 26:505–515.
210. Koprowski, H. 1958. Counterparts of human disease in animals. Ann. N.Y. Acad. Sci. 70:369–382.

211. Kraft, L. M. 1952. Occurrence of coxsackie virus complement fixing antibodies in sera of normal monkeys. Proc. Soc. Exp. Biol. Med. 80:498–502.
212. Kraft, L. M., and J. L. Melnick. 1950. Immunological reactions of the coxsackie viruses. II. The complement-fixation test. J. Exp. Med. 92:483–497.
213. Kraft, L. M., and J. L. Melnick. 1953. Quantitative studies of the virus-host relationship in chimpanzees after inapparent infection with coxsackie viruses. II. The development of complement-fixing antibodies. J. Exp. Med. 97:401–414.
214. Kraus, R., and L. Kantor. 1917. Eshidios sobre la poliomielitis experimental. Rev. Inst. Bacteriol. Dep. Nac. Hig. Argent. 1:43–51.
215. Landsteiner, K., and E. Popper. 1909. Uebertragung der Poliomyelitis Acuta auf Affen. Z. Immunitatsforsch. 2:377–390.
216. Lepine, P., and P. Sidallian. Presence du virus poliomyelitique dans le contenu intestinal d'un enfant vivant en milieu familial infecte. Isolement due virus. C. R. Acad. Sci. 208:129–130.
217. Levaditi, C., S. Nicolau, and R. Schoen. 1926. Recherches sur la rage. Ann. Inst. Pasteur 40:973–1069.
218. Lichter, E. A. 1969. Chimpanzee antibodies to Australia antigen. Nature (London) 244:810–811.
219. Lillie, R. D. 1936. Pathologic histology of lymphocytic choriomeningitis in monkeys. Pub. Health Rep. 51:303–310.
220. Lucas, W. P., and E. L. Prizer. 1912. An experimental study of measles in monkeys. J. Med. Res. 26:181–194.
221. Maass, G., R. Haas, and W. Oehlert. 1969. Experimental infections of monkeys with the causative agent of the Frankfurt-Marburg syndrome (FMS). Lab. Anim. Handbk. 4:155–165.
222. Mackay, E. M., and C. R. Schroeder. 1935. Resistance of the spider monkey (*Ateles ater*) to infection with the virus of acute anterior poliomyelitis. Proc. Soc. Exp. Biol. Med. 33:373–374.
223. Malherbe, H., and R. Harwin. 1957. Seven viruses isolated from the vervet monkey. Brit. J. Exp. Pathol. 38:539–541.
224. Malherbe, H., and R. Harwin. 1963. The cytopathic effects of vervet monkey viruses. S. Afr. Med. J. 37:407–411.
225. Malherbe, H., R. Harwin, and M. Ulrich. 1963. The cytopathic effects of vervet monkey viruses. S. Afr. Med. J. 37:407–411.
226. Malherbe, H., and M. Strickland-Cholmeley. 1967. Simian virus SA11 and the related O agent. Arch. Gesamte Virusforsch. 22:325–245.
227. Malherbe, H., and M. Strickland-Cholmeley. 1969. Virus from baboons. Lancet 2:1300.
228. Malherbe, H., and M. Strickland-Cholmeley. 1969. Simian herpesvirus SA8 from a baboon. Lancet 2:1427.
229. Malherbe, H., and M. Strickland-Cholmeley. 1971. South African studies on the Marburg virus. *In* Proc. Symp. Marburg virus disease. Springer-Verlag, Berlin.
230. Martin, G. V., and R. B. Heath. 1969. Rhinovirus infection of vervet monkeys: a model of human rhinovirus disease. Brit. J. Exp. Pathol. 50:516–519.
231. Mattingly, S. F. 1966. Major zoonoses of primates. J. Amer. Vet. Med. Ass. 149:1677–1680.
232. Matumoto, M. 1969. Mechanism of perpetuation of animal viruses in nature. Bacteriol. Rev. 33:404–418.
233. Mayor, H. D., and M. Ito. 1967. Distribution of antibodies to type 4 adeno-associated satellite virus in simian and human sera. Proc. Soc. Exp. Biol. Med. 126:723–725.
234. McCarthy, K., E. Thorpe, A. C. Laursen, C. S. Heymann, and A. J. Beale. 1968. Exanthematous disease in patas monkeys caused by a herpes virus. Lancet 2:856–857.
235. McConnell, S. J., Y. F. Herman, D. E. Mattson, and L. Erickson. 1962. Monkey pox disease in irradiated cynomolgus monkeys. Nature (London) 195:1128–1129.
236. McMillen, J., F. Macasaet, M. Lenahan, P. Kamitsuka, and H. A. Wenner. 1968. Lack of serologic relationship between several group A coxsackie and simian viruses. Amer. J. Epidemiol. 88:126–131.
237. Melendez, L. V., M. D. Daniel, R. D. Hunt, and F. G. Garcia. 1968. An apparently new herpesvirus from primary kidney cultures of the squirrel monkey (*Saimiri sciureus*). Lab. Anim. Care 18:374–381.
238. Melendez, L. V., C. Espana, R. D. Hunt, M. D. Daniel, and F. G. Garcia. 1969. Natural herpes simplex infection in the owl monkey (*Aotus trivirgatus*). Lab. Anim. Care 19:38–45.
239. Melendez, L. V., F. G. Garcia, C. E. O. Fraser, R. D. Hunt, and N. W. King. 1969. *Herpesvirus saimiri*. I. Further characterization studies of a new virus from the squirrel monkey. Lab. Anim. Care 19:372–377.
240. Melendez, L. V., R. D. Hunt, M. D. Daniel, and B. F. Trum. 1970. New World monkeys, herpes viruses, and cancer, 111–117. *In* H. Balner and W. I. B. Beveridge (ed.), Infections and immunosuppression in subhuman primates. Munksgaard, Copenhagen.
241. Melendez, L. V., R. D. Hunt, F. G. Garcia, and B. F. Trum. 1966. A latent herpes-T infection in *Saimiri sciureus* (squirrel monkey), p. 393–397. *In* R. N. T-W-Fiennes (ed.), Some recent developments in comparative medicine. Academic Press Inc., London.
242. Melnick, J. L. 1968. Discussion of transmission of human viral hepatitis to nonhuman primates., p. 99–103. *In* M. Pollard (ed.), Perspectives in virology, vol 4. Academic Press Inc., New York.
243. Melnick, J. L., and D. D. Banker. 1954. Isolation of B virus (herpes group) from the central nervous system of a rhesus monkey. J. Exp. Med. 100:181–194.
244. Melnick, J. L., M. Benyesh-Melnick, D. J. Fernbach, C. F. Phillips, and R. R. Mirkovic. 1967. The newborn baboon as a test animal for human leukemia and for surveying human viruses for oncogenicity, p. 669–681. *In* H. Vagtborg (ed.), The baboon in medical research, vol. 2. Univ. of Texas Press, Austin.
245. Melnick, J. L., and A. S. Kaplan. 1953. Quantitative studies of the virus-host relationship in chimpanzees after inapparent infection with coxsackie viruses. I. The virus carrier state and the development of neutralizing antibodies. J. Exp. Med. 97:367–400.
246. Melnick, J. L., M. Midulla, I. Wimberly, J. G. Barrerra-Oro, and B. M. Levy. 1964. A new member of the herpesvirus group isolated from S. American marmosets. J. Immunol. 92:596–601.
247. Meyer, H. M., Jr., B. E. Brooks, R. D. Douglas, and N. G. Rogers. 1962. Ecology of measles in monkeys. Amer. J. Dis. Child. 103:307–313.
248. Meyers, H. M., Jr., H. E. Hopps, N. G. Rogers, B. E. Brooks, B. C. Bernheim, W. P. Jones, A. Nisalak, and R. G. Douglas. 1966. Studies on simian virus 40. J. Immunol. 88:796–806.
248*a*. Morgan, H. R. 1967. Antibodies for rous sarcoma virus (Bryan) in fowl, animal, and human populations of East Africa. II. Antibodies in domestic chickens, wildfowl, primates, and man in Kenya, and antibodies for Burkitt lymphoma cells in man. J. Nat. Cancer Inst. 39:1229–1234.
249. Morris, J. A., R. E. Blount, Jr., and R. E. Savage. 1956. Recovery of cytopathogenic agent from chimpanzees with coryza. Proc. Soc. Exp. Biol. Med. 92:544–549.
250. Morris, J. A., K. M. Johnson, C. G. Anlisio, R. M. Chanock, and V. Knight. 1961. Clinical and serologic responses in volunteers given vacuolating virus (SV40) by respiratory route. Proc. Soc. Exp. Biol. Med. 108:56–59.
251. Muckenfuss, R. S., C. Armstrong, and H. A. McCordock. 1933. Encephalitis: studies on experimental transmission. Pub. Health Rep. 48:1341–1343.
252. Munroe, J. S., and W. F. Windle. 1963. Tumors induced in primates by chicken sarcoma virus. Science 140:1415–1416.

253. Murphy, G. P., H. D. Brede, E. Cohen, and J. T. Grace, Jr. 1970. The Cape Western baboon in organ allotransplantation. Transplant. Proc. 2:546–549.
254. Nagler, F. P., and M. Klotz. 1958. A fetal B virus infection in a person subject to recurrent herpes labialis. Can. M. Ass. J. 79:743–745.
255. Nelson, B., G. E. Cosgrove, and N. Gengozian. 1966. Diseases of an imported primate *Tamarinus nigricollis*. Lab. Anim. Care 16:255–275.
256. Nicolle, C., and E. Conseil. (presentee par M. E. Roux). 1911. Reproduction experimentale de la rougeole chez le Bonnet chinois. Virulence du sang des malades 24 heures avant le debut de l'eruption. C. R. Acad. Sci. 153:1522–1524.
257. Nicolle, C., and E. Conseil. 1920. La virulence du sang des rougeoleux n'est pas contestable. C. R. Soc. Biol. 83:56–58.
258. Niederman, J. C., R. W. McCollum, G. Henle, and W. Henle. 1968. Infectious mononucleosis. Clinical manifestations in relation to EB virus antibodies. J. Amer. Med. Ass. 203:205–209.
259. Noble, J. 1970. A study of new and old world monkeys to determine the likelihood of a simian reservoir of smallpox. Bull. W.H.O. 42:509–514, 1970.
260. Ohwada, Y., Y. Yamane, T. Nagashima, M. Takada, T. Asahara, and S. Kashara. 1970. Holding status of antibodies against virus in *Cercopithecus aethiops* and *Macaca irus*. Jap. J. Vet. Sci. 32:69–80.
261. Parkman, P. D., P. E. Phillips, R. L. Kirschstein, and H. M. Meyer, Jr. 1965. Experimental rubella virus infection in the rhesus monkey. J. Immunol. 95:743–752.
262. Pasteur, L., M. M. Chamberland, and M. E. Roux. 1884. Physiologie experimentale-Nouvelle communication sur la rage. C. R. Acad. Sci. 98:457–463.
263. Pasteur, L., M. M. Chamberland, and M. E. Roux. 1884. Pathologie experimentale-sur la rage. C. R. Acad. Sci. 98:1229–1235.
264. Paul, J. R., J. L. Melnick, and A. B. Sabin. 1948. Experimental attempts to transmit Phlebotomus (Sandfly, Pappatici) and dengue fevers to chimpanzees. Proc. Soc. Exp. Biol. Med. 68:193–198.
265. Paul, J. R., and J. D. Trask. 1932. The detection of poliomyelitis virus in so called abortive types of the disease. J. Exp. Med. 56:319–343.
266. Pedreira, F. A., N. M. Tauraso, and A. E. Palmer. 1968. Attempts to infect rhesus monkeys with human type 4 adenovirus. Proc. Soc. Exp. Biol. Med. 129:472–477.
267. Phillips, P. E., P. D. Parkman, R. L. Kirschstein, and H. M. Meyer, Jr. 1965. Experimental rubella virus infection in the rhesus monkey. Fed. Proc. 24:570.
268. Pierce, E. C., J. D. Pierce, and R. N. Hull. 1958. B virus: its current significance, description and diagnosis of a fatal human infection. Amer. J. Hyg. 68:242–250.
269. Pinto, C. A., and R. F. Haff. 1969. Experimental infection of gibbons with rhinovirus. Nature (London) 224:1310–1311
270. Prier, J. E., and R. M. Sauer. 1960. A pox disease of monkeys. Ann. N.Y. Acad. Sci. 85:951–959.
271. Prier, J. E., R. M. Sauer, R. G. Malsberger, and J. M. Sillaman. 1960. Studies on a pox disease of monkeys. II. Isolation of the etiologic agent. Amer. J. Vet. Dis. 21: 381–384.
272. Prince, A. M. 1971. Hepatitis associated antigen; Longterm persistence in chimpanzees. *In* J. Moor-Jankowski and E. I. Goldsmith (ed.), 2nd Conf. Exp. Med. Surg. Primates. S. Karger, Basel, *in press*.
273. Proceedings of a symposium on cross-species transplantation, K. Reemtsma (chairman). 1970. Transplant. Proc. 2:431–559.
274. Rabotti, G. F., J. C. Landon, T. W. Pry, L. Beadle, J. Doll, D. P. Fabrizio, and A. J. Dalton. 1967. Tumors in rhesus monkeys inoculated at birth with homologous cells converted in vitro by rous sarcoma virus, Schmidt Ruppin strain. J. Nat. Cancer Inst. 38:821–837.
275. Rake, G., and M. F. Shaffer. 1940. Studies on measles; use of chorioallantoic of developing chicken embryo. J. Immunol. 38:177–200.
276. Rapoza, N. P., and R. W. Atchinson. 1967. Association of AAV-1 with simian adenoviruses. Nature (London) 215: 1186–1187.
277. Rapp, F., S. S. Tevethia, W. E. Rawl, and J. L. Melnick. 1967. Production of antibodies to papova-virus SV40 tumor antigen in African green monkeys. Proc. Soc. Exp. Biol. Med. 125:794–798.
278. Rivers, T. M. 1926. Nuclear inclusions in the testicles of monkeys infected with the tissue of human varicella lesions. J. Exp. Med. 43:275–287.
279. Rivers, T. M. 1927. Varicella in monkeys. Nuclear inclusions produced by varicella virus in the testicles of monkeys. J. Exp. Med. 45:961–968.
280. Robbins, F. C., and J. F. Enders. 1950. Tissue culture technique in the study of animal viruses. Amer. J. Med. Sci. 220:316–338.
281. Rogers, N. G., M. Basnight, C. J. Gibbs, Jr., and D. C. Gajdusek. 1967. Latent viruses in chimpanzees with experimental kuru. Nature (London) 216:446–449.
282. Rowe, W. P., R. J. Huebner, L. K. Gilmore, R. H. Parrott, and T. G. Ward. 1953. Isolation of a cytopathogenic agent from human adenoids undergoing spontaneous degeneration in tissue culture. Proc. Soc. Exp. Biol. Med. 84:570–573.
283. Ruch, T. C. 1959. Diseases of laboratory primates. W. B. Saunders Co., Philadelphia.
284. Ruckle, G. 1958. Studies with the monkey-intranuclear inclusions agent (MINIA) and foamy agent derived from spontaneously degenerating monkey kidney cultures. I. Isolation and tissue culture behavior of the agents and identification of MINIA as closely related to measles virus. Arch. Gesamte Virusforsch. 8:139–166.
285. Ruckle, G. 1958. Studies with the monkey-intranuclear inclusions agent (MINIA) and foamy agent derived from spontaneously degenerating monkey kidney cultures. II. Immunologic and epidemiologic observation in monkeys in a laboratory colony. Arch. Gesamte Virusforsch. 8: 167–182.
286. Rustigian, R., P. B. Johnston, and H. Reihart. 1955. Infection of monkey kidney tissue cultures with virus-like agents. Proc. Soc. Exp. Biol. Med. 88:8–16.
287. Sabin, A. B. 1934. Studies on the B virus. III. The experimental disease in *Macacus rhesus* monkeys. Brit. J. Exp. Pathol. 15:321–334.
288. Sabin, A. B. 1959. Reoviruses—a new group of respiratory and enteric viruses formerly classified as ECHO type 10 is described. Science 130:1387–1389.
289. Sabin, A. B., and A. M. Wright. 1934. Acute ascending myelitis following a monkey bite with the isolation of a virus capable of reproducing the disease. J. Exp. Med. 59:115–136.
290. Saddington, R. S. 1932. An intravascular lesion in poliomyelitis induced by feeding in *Macacus cynomolgus*. Proc. Soc. Exp. Biol. Med. 29:838–839.
291. Saslaw, S., and H. N. Carlisle. 1969. Use of subhuman primates in experimental infections. Ann. N.Y. Acad. Sci. 162:568–586.
292. Schmidt, N. J., J. Dennis, E. H. Lennette, H. H. Ho, and T. T. Shinomoto. 1965. Antibody responses of rhesus (*Macaca mulatta*) monkeys experimentally infected with coxsackieviruses of group B and group A, type 9. J. Immunol. 95:54–69.
293. Schultz, E. W., and K. Habel. 1959. SA virus. A new member of the myxovirus group. J. Immunol. 82:274–278.
294. Schwartz, A., and W. P. Allen. 1970. Experimental infection of monkeys with Bunyamwera and Germiston viruses. Infec. Immun. 2:762–766.

295. Sever, J. L. 1962. Application of a microtechnique to viral serological investigations. J. Immunol. 88:320–329.
296. Sever, J. L., G. W. Meier, W. F. Windle, G. M. Schiff, G. R. Monif, and A. Fabiyi, A. 1966. Experimental rubella in pregnant rhesus monkeys. J. Infec. Dis. 116:21–26.
297. Sever, J. L., G. M. Schiff, and R. G. Traub. 1962. Rubella virus. J. Amer. Med. Ass. 182:663–671.
298. Shaffer, M. F., G. Rake, J. Stokes, and G. C. O'Neil. 1941. Studies on measles; experimental disease in man and monkey. J. Immunol. 41:241–257.
299. Shah, K. V. 1966. Neutralizing antibodies to simian virus 40 (SV40) in human sera from India. Proc. Soc. Exp. Biol. Med. 121:303–307.
300. Shah, K. V., and D. M. Hess. 1968. Presence of antibodies to simian virus 40 (SV40) T antigen in rhesus monkeys infected experimentally or naturally with SV40. Proc. Soc. Exp. Biol. Med. 128:480–485.
301. Shah, K. V., and J. A. Morrison. 1969. Comparison of three rhesus groups for antibody patterns to some viruses: absence of active simian virus 40 transmission in the free-ranging rhesus of Cayo Santiago. Amer. J. Epidemiol. 89:308–315.
302. Shah, K. V., and C. H. Southwick. 1965. Prevalence of antibodies to certain viruses in sera of free-living rhesus and of captive monkeys. Indian J. Med. Res. 53:488–500.
303. Shah, K. V., S. Willard, R. E. Myers, D. M. Hess, and R. DiGiacomo. 1969. Experimental infection of rhesus with simian virus 40 (SV40). Proc. Soc. Exp. Biol. Med. 130: 196–203.
304. Sheldon, W. G., and M. A. Ross. 1966. A generalized herpes virus infection in owl monkeys, p. 1–22. U.S. Army Med. Res. Lab. Rep. no. 670, DA Project no. 3A014501B71P.
305. Shishido, A. 1966. Natural infection of measles virus in laboratory monkeys. Jap. J. Med. Sci. Biol. 19:221–222.
306. Shope, R. E. 1965. Transmission of viruses and epidemiology of viral infections, p. 385–404. *In* F. L. Horsfoll and I. Tamm (ed.), Viral and rickettsial infections of man, 4th ed. J. B. Lippincott Co., Philadelphia.
307. Shortt, H. E., C. G. Pandit, W. M. E. Anderson, and R. S. Rao. 1940. Sandfly fever virus; certain of its properties and an attempt at prophylactic vaccination. Indian J. Med. Res. 27:847–863.
308. Shulman, N. R., R. J. Hirschman, and L. F. Barker. 1971. Identification of the virus like antigen of human hepatitis in nonhuman primates. *In* J. Moor-Jankowski and E. I. Goldsmith (ed.), 2nd Conf. Exp. Med. Surg. Primates. S. Karger, Basel, *in press*.
309. Sibal, L. R., M. A. Fink, C. L. McCune, and C. A. Cowles. 1967. Antibody response of rhesus monkeys to a density gradient purified murine leukemia virus. J. Immunol. 98:368–373.
310. Siegert, R., H. L. Shu, and W. Slenczka. 1968. Isolierung und Identifizierung des "Marburg-Virus." Deut. Med. Wochenschr. 93:604–612.
311. Sigurdardottir, B., K. F. Givan, K. R. Rozee, and A. J. Rhodes. 1963. Association of virus with cases of rubella studied in Toronto; propagation of the agent and transmission to monkeys. Can. Med. Ass. J. 88:128–132.
312. Simmons, J. S. 1940. Dengue fever, p. 349–364. *In* Virus and rickettsial diseases. Harvard Univ. Press, Cambridge, Mass.
313. Simmons, J. S., J. H. St. John, and F. H. K. Reynolds. 1931. Experimental studies of dengue, p. 19–77, 112–146, 189–247, *In* Manila Bureau of Science, Monogr. no. 29.
314. Simpson, D. I. H. 1969. Marburg virus disease: experimental infection of monkeys. Lab. Anim. Handb. 4:149–154.
315. Slenczka, W. 1971. Biological properties of the marburg virus. *In* Proc. Symp. Marburg virus disease. Springer-Verlag, Beriin.
316. Slenczka, W., H-L Shu, G. Piepenburg, and R. Siegert. 1968. Antigen-Nachweis des "Marburg-Virus" in den Organen infizierter Meerschweinchen durch Immunofluoreszenz. Deut. Med. Wochenschr. 93:612–616.
317. Smith, K. O., J. F. Thiel, J. T. Newman, E. Harvey, M. D. Trousdale, W. D. Gehle, and G. Clark. 1969. Cytomegaloviruses as common contaminants in primary African green monkey kidney cell cultures. J. Nat. Cancer Inst. 42:489–496.
318. Smithburn, K. C., and A. J. Haddow. 1944. Semliki Forest virus. I. Isolation and pathogenic properties. J. Immunol. 49:141–157.
319. Smithburn, K. C., T. P. Hughes, A. W. Burke, and J. H. Paul. 1940. Neurotropic virus isolated from blood of native of Uganda. Amer. J. Trop. Med. 20:471–492.
320. Soike, K. F., F. Coulston, P. Day, R. Deibel, and H. Plager. 1967. Viruses of the alimentary tract of chimpanzees. Exp. Mol. Pathol. 7:259–303.
321. Soike, K. F., F. Coulston, and J. D. Douglas. 1969. Further studies on the viruses of the chimpanzee. I. Viral infection of colony-maintained chimpanzees. Exp. Mol. Pathol. 11:323–332.
322. Soike, K. F., J. D. Douglas, H. Plager, and F. Coulston. 1969. Further studies of the viruses of the chimpanzee. II. Viral infection in recently imported chimpanzees captured in Africa. Exp. Mol. Pathol. 11:333–339.
323. Srihongse, S. 1969. Vesicular stomatitis virus infections in Panamanian primates and other vertebrates. Amer. J. Epidemiol. 90:69–76.
324. Stiles, G. E. 1968. Serologic screening of rhesus and grivet monkeys for SV40 and the foamy viruses. Proc. Soc. Exp. Biol. Med. 127:225–230.
325. Stojkovic, Lj., M. Bordjoski, A. Gligic, and Z. Stefanovic. 1971. Etiology and epidemiology of two human cases of vervet monkey-associated haemorrhagic fever in Belgrade. *In* Proc. Symp. Marburg virus disease. Springer-Verlag, Berlin.
326. Stokes, A., J. H. Bauer, and N. P. Hudson. 1928. Experimental transmission of yellow fever to laboratory animals. Amer. J. Trop. Med. 8:103–164.
327. Swan, C., and J. Mawson. 1943. Experimental mumps: transmission of the disease to monkeys: attempts to propagate the virus in developing hen's eggs. Med. J. Aust. 1:411–416.
328. Tauraso, N. M., S. S. Kalter, J. J. Ratner, and R. L. Heberling. 1971. Simian hemorrhagic fever. *In* J. Moor-Jankowski and E. I. Goldsmith (ed.), Proc. 2nd Conf. Exp. Med. Surg. Primates, *in press*.
329. Tauraso, N. M., M. G. Myers, K. McCarthy, and G. W. Tribe. 1970. Simian hemorrhagic fever, p. 101–109. *In* H. Balner and W. I. B. Beveridge (ed.), Infections and immunosuppression in subhuman primates. Munksgaard, Copenhagen.
330. Taylor, R. M., M. A. Haseeb, and T. H. Work. 1955. A regional reconnasisance on yellow fever in the Sudan. With special reference to primate hosts. Bull. W.H.O. 12:711–725.
331. Teissier, P., P. Gastinel, and J. Reilly. 1925. Sur l'herpes du singe. C. R. Acad. Sci. 92:1015–1017.
332. Teissier, P., J. Reilly, E. Rivalier, and V. Stifanesco. 1931. Les infections varioliques inapparentes. C. R. Soc. Biol. 108:1039–1041.
333. Tesh, R., P. Peralta, and K. Johnson. 1969. Ecologic studies of vesicular stomatitis virus. I. Prevalence of infection among animals and humans living in an area of endemic VSV activity. Amer. J. Epidemiol. 90:255–261.
334. Theiler, M., and S. Gard. 1940. Encephalomyelitis of mice; characteristics and pathogenesis of virus. J. Exp. Med. 72: 49–67.
335. Theiler, M., and S. Gard. 1940. Encephalomyelitis of mice; epidemiology. J. Exp. Med. 72:79–90.
336. Thomas, H. W. 1907. Yellow fever in the chimpanzee. Brit. Med. J. 1:1138.
337. Thomsen, O. 1912. Experimentelle Untersuchungen uyer die Poliomyelitis. Z. Immunitaetsforsch. Aller. Klin. Immunol. 14:198–217.
338. Trask, J. D., and J. R. Paul. 1941. Experimental poliomyelitis

in *Cercopithecus aethiops sobaeus* (the green African monkey) by oral and other routes. J. Exp. Med. 73:453–459.

339. Tribe, G. W. 1966. An investigation of the incidence, epidemiology and control of simian virus 5. Brit. J. Exp. Pathol. 47:472–479.
340. Trum, B. F., and J. K. Routledge. 1967. Common disease problems in laboratory animals. J. Amer. Vet. Med. Ass. 151:1886–1896.
341. Valerio, D. A., K. D. Courtney, R. L. Miller, and A. J. Pallotta. 1968. The establishment of a *Macaca mulatta* breeding colony. Lab. Anim. Care 18:589–595.
342. Van Hoosier, G. L., Jr., and J. L. Melnick. 1961. Neutralizing antibodies in human sera to *Herpesvirus simiae* (B virus). Tex. Rep. Biol. Med. 19:376–380.
343. Van Rooyen, C. E., and A. J. Rhodes. 1948. Ascending myelitis due to B virus, p. 1202–1163. *In* Virus diseases of man, 2nd ed. Thomas Nelson & Sons, New York.
344. Vickers, J. H. 1962. Procurement of measles-susceptible rhesus monkeys. Amer. J. Dis. Child. 103:342–344.
345. Vickers, J. H. 1969. Diseases of primates affecting the choice of species for toxicologic studies. Ann. N. Y. Acad. Sci. 162:659–672.
346. Vižnec, A. J., J. R. Paul, and J. D. Trask. 1939. Poliomyelitic virus from feces in nonparalytic poliomyelitis; infectivity by various routes. Proc. Soc. Exp. Biol. Med. 41:246–250.
347. Von Magnus, P., E. K. Anderson, K. B. Petersen, and A. Birch-Anderson. 1959. A pox-like disease in cynomolgus monkeys. Acta Pathol. Microbiol. Scand. 46:156–176.
348. Wedum, A. G., and R. H. Kruse. 1969. Assessment of risk of human infection in the microbiological laboratory. Misc. Pub. 30, 2nd ed., Dept. of the Army, Fort Detrick, Frederick, Md.
349. Wenner, H. A., C. R. Bolano, and C. T. Cho. 1969. Studies on pathogenesis of monkey pox. III. Histopathological lesions and sites of immunofluorescence. Arch. Gesamte Virusforsch. 27:179–197.
350. Wenner, H. A., C. Bolano, C. T. Cho, and P. S. Kamitsuka. 1969. Monkey pox. IV. Modification of disease pattern by antilymphocytic sera. J. Infec. Dis. 120:318–331.
351. Wenner, H. A., C. T. Cho, C. R. Bolano, and P. S. Kamitsuka. 1969. Studies on the pathogenesis of monkey pox. II. Dose-response and virus dispersion. Arch. Gesamte Virusforsch. 27:166–178.
352. Wenner, H. A., P. Kamitsuka, F. Macasaet, and P. Kidd. 1968. Pathogenesis of monkey pox, p. 40–44. Antimicrob. Ag. Chemother. 1967, American Society for Microbiology, Ann Arbor, Mich.
353. Wenner, H. A., F. D. Macasaet, and P. S. Kamitsuka. 1968. Monkey pox. I. Clinical, virologic and immunologic studies. Amer. J. Epidemiol. 87:551–566.
354. Wising, P. J. 1939. Some experiments with lymph gland material from cases of infectious mononucleosis. Acta Med. Scand. 98:328–339.
355. Wising, P. J. 1942. Study of infectious mononucleosis (Pfeiffer's disease) from etiological point of view. Acta Med. Scand. Suppl. 133:1–102.
356. Woolpert, O. C., J. L. Schwab, S. Saslaw, C. Merino, and C. A. Doan. 1941. Response to influenza virus A. Proc. Soc. Exp. Biol. Med. 48:558–560.
357. Yamanouchi, K., A. Fukuda, F. Kobune, M. Hikita, and A. Shishido. 1969. Serologic survey with the sera of monkeys in regard to their natural infection with measles virus. Jap. J. Med. Sci. Biol. 22:117–121.
358. Yamanouchi, K., A. Fukuda, F. Kobune, N. Uchida, and T. Tsuruhara. 1967. Oncogenicity of Schmidt-Ruppin strain of rous sarcoma virus in cynomolgus monkeys. Jap. J. Med. Sci. Biol. 20:443–446.
359. Zietlyonok, N. A., M. Y. Chumakova, N. M. Ralph, and L. S. Goen. 1966. Distribution area and natural hosts of latent viruses of monkeys. Occurrance of simian vacuolating virus (SV40) and *Herpesvirus simiae* in Cynomolgus monkeys in Indonesia. Acta Virol. 10:537–541.
360. Zilber, L. A., B. A. Lapin, and F. I. Adgighytov. 1963. Pathogenicity of Rous sarcoma virus for monkeys. Nature (London) 205:1123–1124.
361. Zilber, L. A., B. A. Lapin, F. I. Adgighytov, V. J. Shevljaghyn, and L. A. Jakovleva. 1966. Rous tumors in monkeys. Int. J. Cancer 1:395–407.