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Smallpox and Monkeypox in Non-human Primates

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In considering global eradication of smallpox the absence of an animal reservoir is important. Present knowledge of experimental infection of non-human primates with variola virus and of a related virus infection in monkeys, termed monkeypox, is examined.

From the literature review and the results of a survey of captive monkeys in 26 major biological institutions it is concluded that outbreaks of supposed smallpox and monkeypox are not frequent and that man may be comparatively insusceptible to monkeypox. A natural reservoir of smallpox in non-human primates is thought to be unlikely although further studies are warranted since the survey reveals that certain species of monkeys can be infected with smallpox and that infected monkeys can transmit infection to others.

A significant consideration in the world-wide smallpox eradication programme now under way is the absence of any known animal reservoir. Eradication programmes for yellow fever and malaria were initiated in the belief that animal reservoirs were non-existent, but subsequent studies showed these assumptions to be incorrect. Therefore, in the smallpox eradication programme a continuing search for evidence of a possible reservoir of smallpox in non-human primates is appropriate and attention must be paid to the recently recognized monkeypox virus which closely resembles variola virus.

REPORTED SMALLPOX OR NATURALLY OCCURRING POX INFECTIONS IN NON-HUMAN PRIMATES

Of particular interest are reports of supposed smallpox in primates as well as reports of naturally occurring epidemics of pox infections among primate populations. Only 7 such episodes are known and only 3 occurred during the present century. In only one instance was virological study undertaken and this was a decade before the recognition of monkeypox as an additional entity in the pox virus complex (Table 1).

The single episode confirmed by virus isolation was reported by Gispen (1949). He observed 2 orang-utans in a Djakarta zoo which contracted a pox infection at the time of a smallpox epidemic in the area. Both orang-utans were in the same cage and demonstrated typical lesions on the face, hands, and soles of the feet; one died. A virus was isolated in chick embryos from both affected animals. It induced lesions resembling those produced by variola virus when inoculated on rabbit cornea. Other monkeys in the zoo, none of which had been previously vaccinated, remained unaffected. It was suspected that the animals were infected from humans, since at that time ambulant smallpox cases were frequent.

An outbreak of pox infections was observed by M. A. Rahman (personal communication, 1967) in rhesus monkeys in Bengal, India, in 1936. Many deaths were observed in monkeys living in mango groves near the town and which visited the town frequently in search of food and water. The sick monkeys were quiet and lethargic and had pustular lesions particularly on the face, palms and soles. When they died they fell from the trees and roof tops, and the carcasses were disposed of without particular precautions. Despite a known poor immunity status in the population, no human pox-like illnesses were observed.

Smallpox infection in a monkey population in the Brazilian forest was reported by Bleyer (1922). " Carcasses of the monkeys (*Mycetes seniculus* and *Cebus capucinus*) were found under the trees, the dead animals having fallen from the tree-tops. The sick monkeys as well as the dead ones were covered with numerous smallpox pustules. Cebus monkeys

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TABLE 1
NATURALLY OCCURRING POX INFECTION IN NON-HUMAN PRIMATES

Region	Year	Species	Author
France	1767	?	Barrier, quoted by Schmidt (1870)
Panama	1841	?	Anderson (1861)
France	1842	?	Rayer, quoted by Schmidt (1870)
Trinidad	1858	?	Furlong, quoted by Schmidt (1870)
Brazil	1922	*Mycetes seniculus* *Cebus capucinus*	Bleyer (1922)
India	1936	*Macaca mulatta*	M. A. Rahman (personal communication 1967)
Indonesia	1949	Orang-utan [a]	Gispen (1949)

[a] Virus isolation was performed.

suffering from the disease were seen in a state of distress wringing their hands. The mortality among the animals from the smallpox was extremely high in certain districts."

Anderson (1861) reported a smallpox outbreak observed in 1841 in a monkey population followed by a smallpox outbreak in a human population in Panama. Two monkeys examined were found to be covered by pustulation.

Schmidt (1870) mentioned three other episodes: "Barrier reported that in 1767, an inhabitant of Saint-Germain-en-Laye observed that a monkey playing with children infected with smallpox subsequently suffered from the disease . . . Rayer in 1842 reported smallpox in monkeys. Furlong reported smallpox in wild monkeys in Trinidad in 1858."

Considering the extent and prevalence of smallpox in Asia, Africa and America, in areas where non-human primates are numerous, the paucity of available reports of pox infections is remarkable. In fact, so far as is known, no outbreaks of pox infections in nature have been recorded since 1936.

MONKEYPOX

Recognition of monkeypox

The first description of monkeypox as a specific entity in the group of pox virus diseases was recorded by von Magnus et al. (1959). Since then, 3 outbreaks of monkeypox have been reported, by Prier et al. (1960) and Sauer et al. (1960), by McConnell et al. (1962) and by Peters (1966), respectively. The virus was isolated from each outbreak either on the chorioallantoic membrane (CAM) of chick embryos or in monkey kidney or rabbit kidney tissue cell culture. It was established that the causative agent belongs to the variola-vaccinia group in the poxvirus complex because of the physical appearance of the organism (rectangular with a "diameter" of 200 mμ to 250 mμ) (von Magnus et al., 1959), the formation of intracytoplasmic eosinophilic inclusion bodies (Sauer et al., 1960), clinical manifestation of pox in the skin (von Magnus et al., 1959; McConnell et al., 1962; Peters, 1966; Prier et al., 1960; Sauer et al., 1960) and the serological relationship with vaccinia virus (von Magnus et al. 1959; McConnell et al., 1962; Prier et al., 1960).

The virus resembles in its properties both variola virus and vaccinia virus (Table 2). On CAM the virus forms a small whitish lesion which is similar to the lesion produced by variola virus, and in rabbits it induces keratitis like that produced by variola virus. It resembles vaccinia virus in that it can be passed serially in rabbit skin; it is fatal when injected intracerebrally into 3-week-old mice; and it induces plaque formation in monolayer chick embryo tissue cell culture. However, the monkeypox virus differs from variola and vaccinia viruses by causing haemorrhagic, necrotic lesions in rabbit skin. No differences were observed among these 3 viruses in the diffusion-in-gel test.

The clinical features of the disease have been described by Sauer et al. (1960), and their description is paraphrased as follows:

Among animals with natural infection no sign of illness was noted before the appearance of cutaneous

TABLE 2
PROPERTIES OF VARIOLA, VACCINIA AND MONKEYPOX VIRUSES

Characteristic	Variola	Vaccinia	Monkeypox	References
Lesion on CAM	Small	Large	Small	Gispen et al. (1967); von Magnus et al. (1959); Prier et al. (1960)
Rabbit skin passage	—	+	+	Gispen et al. (1967); von Magnus et al. (1959); McConnell et al. (1962); Prier et al. (1960)
Lesion in rabbit skin	Not haemorrhagic	Not haemorrhagic	Haemorrhagic	Gispen et al. (1967)
Keratitis in rabbit cornea	Resembles monkeypox	...	Resembles variola	Gispen et al. (1967); von Magnus et al. (1959)
Pathogenicity in 3-week-old mice (intracerebral route)	—	Fatal	Fatal	von Magnus et al. (1959); McConnell et al. (1962); Prier et al. (1960)
Plaque formation in chick embryo cell culture	—	+	+	McConnell et al. (1964); Mika & Pirsch (1960)
Diffusion-in-gel precipitation test	Viruses appear identical			Gispen et al. (1967)
Antigenic relationship (CF test and HI test)	Viruses appear identical			von Magnus et al. (1959); Prier et al. (1960)
Clinical manifestations in *Macaca irus* by aerosols:				
Generalized eruption	+	—	+	Hahon (1961)
Constitutional disturbance	+	+	+	

lesions, although some individuals showed oedema of the face beginning over the bridge of the nose. Usually the cutaneous disease appeared as a single crop, consisting of multiple, discrete, blanched, shot-like papules varying in diameter from less than 1 mm to approximately 4 mm. These lesions appeared over the entire trunk and tail, particularly abundant on the palms of the hands and the soles of the feet. The content of the papules became very thick and pus-like and frequently umbilicated. Later these became covered with reddish-brown crusts which fell off in 7–10 days, leaving a small scar. Oral lesions occurred and when they did they were always ulcerated, they were circular, discrete and averaged 2 mm in diameter.

Histological and pathological studies showed that the skin underwent proliferation of the epidermis followed by necrosis. There were focal areas of acanthosis, followed by intracellular oedema producing a large increase in the size of cell body and nucleus. The nucleoli were large, often eosinophilic and frequently paired. Intracellular oedema rarely proceeded to reticular degeneration with the formation of a large vesicle before the onset of necrosis. If this did occur, the area was usually found in the upper half of the epidermis. Inflammatory cells accumulated in the perivascular regions of the dermis; neutrophils invaded the oedematous squamous cells with consequent destruction of the cytoplasm and nucleus but not of the cellular walls, resulting in a spongiform pustule. Rupture of the interstices to form a large confluent pustule was not commonly seen, but multiple small pustules were frequent. Intracytoplasmic inclusion bodies were most numerous in the epidermal cells along the sides of the lesion, but also occurred at the base. These were usually round but frequently somewhat irregular, eosinophilic, and approximately 3μ to 7μ in diameter. Eosinophilic intranuclear inclusions were occasionally seen but never concurrently in a cell with intracytoplasmic inclusion bodies.

Outbreaks of monkeypox

In 1967, the World Health Organization made inquiries of 26 major biological institutions in 10 countries, which handle large numbers of monkeys, to ascertain how frequently monkeypox was being observed, in what species, and whether associated with human infections, etc. The institutions (numbers in parentheses) which submitted information were located in Canada (1), Czechoslovakia (1), Denmark (1), Hungary (1), Italy (1), Sweden (1), France (2), Netherlands (3), United Kingdom (49 and United States of America (11). Altogether)

TABLE 3
MONKEYPOX OR POX-LIKE DISEASE IN BIOLOGICAL INSTITUTIONS

Countries	Episode (see text)	Year	Species of monkeys affected	Origin
Denmark	No. 1 [a]	1958	Cynomolgus	Singapore
Netherlands	No. 2 [a]	1964, 1965	Cynomolgus	?
	No. 3 [a]	1964	Numerous	?
USA	No. 4	?	Rhesus	India
	No. 5 [a]	1959	Mainly *Macaca philippinensis*, *Macaca mulatta*	?
	No. 6	1965	*Macaca irus*	Philippines Malaysia
	No. 7 [a]	1962	Cynomolgus	?
	No. 8	?	Rhesus	India
	No. 9	?	Langur	?

[a] Confirmed by virus isolation.

episodes were recorded during the past decade (Table 3).

Monkeypox outbreaks confirmed by virus isolation

Only 5 outbreaks of monkeypox confirmed by virus isolation have been recognized.

Episode No. 1. Von Magnus et al. (1959) reported 31 cases of monkeypox in cynomolgus monkeys received from Singapore at the Statens Serum-institut, Copenhagen, during 1958. Outbreaks occurred 62 days and 51 days after receipt of shipment and it was felt that, in each outbreak, subclinical carriers of the virus must have been present in the shipment. No monkeys died and no infection occurred in laboratory workers.

Episode No. 2. Gispen & Kapsenberg (1968) reported that on 3 occasions during 1964 and 1965, silent monkeypox virus infections were recognized in cynomolgus colonies in the Netherlands. These were recognized by identification of the virus from uninoculated monkey kidney cell cultures. At no time were pox-like disease symptoms seen in the monkey colony.

Episode No. 3. Peters (1966) reported an outbreak which occurred during December 1964 in the Rotterdam Zoo, where many species of primates were housed. Two giant ant-eaters, recently purchased, became ill with vesicles on the nose, legs, soles of the feet and tongue. Ten days later 2 orang-utans housed in a glass cage near the infected ant-eaters showed pox lesions. Despite containment measures, the infection spread to the entire monkey house in the zoo. Altogether 23 animals developed disease and 11 died. No human cases were noted.

Of the 10 affected orang-utans, 6 died; among chimpanzees, pox eruptions occurred without general constitutional disturbances; 2 infected gorillas survived, although 1 was seriously ill; 4 *Cercopithecus* presented a pox eruption, but they were only mildly ill; 1 marmoset died, although others infected presented only mild clinical symptoms. Deaths were also recorded in a gibbon and 3 squirrel monkeys.

Episode No. 5. Prier et al. (1960) and Sauer et al. (1960) reported an outbreak during 1959 in " gang-housed " monkeys in the animal quarters of Merck Sharp & Dohme, USA. Two thousand captive monkeys (*Macaca philippinensis* 41%, *Macaca mulatta* 56% and *Cercopithecus aethiops* var. *sabaeus* 3%) were located in several rooms but were incompletely separated. At the time of the outbreak, a dozen of the animals showed disease, but it is believed that as many as 10% of the animals had been infected. A high frequency of infection was observed in the *Macaca philippinensis*; comparatively few infections occurred in the *Macaca mulatta*. The

case fatality rate was less than 0.5%. No human infections were noted.

Episode No. 7. McConnell et al. (1962) reported 3 cases of monkeypox in cynomolgus monkeys at Walter Reed Army Institute of Research, Washington, D.C., during 1962. The first case occurred 45 days after whole-body irradiation. A few days later another irradiated animal developed the disease. A third case occurred in a non-irradiated animal.

Twenty-five sera from the group of 27 cynomolgus monkeys in which the disease occurred showed haemagglutination-inhibiting (HI) antibodies (monkeypox antigen), while in a group of 45 cynomolgus monkeys in which no disease occurred, only 11% showed HI antibody. Among 67 rhesus monkeys, 52 showed HI antibodies and, in 14 African green monkeys, 6 had HI antibodies, suggesting that extensive subclinical infection had been present. No infection of laboratory workers was observed.

Other instances of pox-like disease unconfirmed virologically

Four institutions which use large numbers of monkeys noted clinical conditions compatible with monkeypox but virus isolation was not attempted.

Episode No. 4. Lederle Laboratories, USA, which handle as many as 8000 monkeys a year, have noted no outbreaks as such but a few single monkeys with pox disease have been observed (J. H. Vickers, personal communication, 1967). All afflicted monkeys were approximately 2–3-year-old rhesus monkeys recently arrived from India.

Episode No. 6. In November 1965, at the Pitman Moore Biological Laboratories, USA, 15 *Macaca irus* monkeys were found to have skin lesions compatible with monkeypox, which developed several weeks after receipt from either the Philippines or Malaysia (A H. Brueckner, personal communication, 1967). Histological examination of the skin showed hypertrophy and hyperplasia of the epidermal cells, marked swelling of individual cells and eosinophilic cytoplasmic inclusions in some cells.

Episode No. 8. Wyeth Laboratories, USA, reported having observed less than 12 instances of pox disease, all of which occurred in rhesus monkeys arriving from India. Lesions were found in most instances upon arrival, but in a few cases, were first noted during the quarantine period. None of the animals was seriously affected; most had only a few to several lesions, over the face and extremities. No disease was found in African green monkeys (M. Z. Bierly, personal communication, 1967).

Episode No. 9. L. H. Schmidt, National Center for Primate Biology, University of California, Davis, Calif., USA, observed a clinical illness in langurs which he considered to be monkeypox or vaccinia, but no cultures were done (K. E. Hamlin, personal communication, 1967).

None of the other laboratories reported having recognized pox disease among animals being processed. Among those which did observe pox infections in monkeys, none noted any pox-like illness in the monkey handlers.

EXPERIMENTAL POX DISEASE IN MONKEYS

Since the beginning of this century, monkeys have been used as experimental animals for immunological studies on the variola-vaccinia group of pox diseases. Horgan & Mansour (1939) and Horgan et al. (1948) have summarized many of these studies. Various species of monkeys have been used, including *Macaca mulatta, Macaca sinicus, Macaca cynomolgus, Macaca nemestrinus* and *Cercopithecus.* In these studies, different routes of inoculation have been appraised, including corneal, palatal, digestive, intravenous, intracerebral, intratesticular, etc.; few, however, have employed the aerosol route which is considered to be the usual natural route of transmission in human smallpox. Considering the diverse methods of inoculation and the different quantities of inoculum employed it is difficult to draw definite conclusions regarding the relative susceptibility of the different species except to note that monkeys are to a greater or lesser extent susceptible to the variola-vaccinia group of viruses.

Hahon (1961) endeavoured to infect *Macaca irus,* obtained from the Philippines, by the aerosol route (mass median diameter less than 5 μ), using viruses of variola major and minor, vaccinia virus, monkeypox virus, cowpox virus, and rabbitpox virus. An elevation of temperature occurred with all the pox virus infections; after 3 days with vaccinia and rabbitpox; after 4 days with variola major and minor and monkeypox; and after 6 days with cowpox. Coughing, coryza and anorexia were observed in the monkeys exposed to vaccinia, rabbitpox and monkeypox viruses, but not in the monkeys exposed to smallpox.

Mild dermal eruption was observed only in animals exposed to smallpox (variola major) and

monkeypox viruses. Papules appeared on the ninth or tenth day after exposure. They were limited to the face and hands and gradually resolved within 3–4 days. Several deaths occurred in animals 6–7 days after exposure to monkeypox virus. Intracytoplasmic inclusion bodies were found in monkeys exposed to vaccinia, rabbitpox, monkeypox and cowpox, but none in monkeys exposed to variola virus.

Neutralizing antibodies were found in surviving monkeys 10–11 days after exposure. The close antigenic relationship between the viruses precluded the identification of specific pox-virus antibodies.

In another study, Hahon & Wilson (1960) found that in *Macaca irus* exposed to variola virus by aerosol, viraemia was observed during the late stages of the incubation period and at the time of development of exanthem. The clinical manifestations of smallpox in the monkey are, to some extent, different from those of human smallpox. The incubation period in the monkey is shorter than in the human; the exanthem is milder and of shorter duration; eruptions occur more frequently on the flexor surfaces than on extensor surfaces, the reverse of the usual pattern in humans.

Westwood et al. (1966) also induced variola infections in Indian rhesus monkeys (*Macaca mulatta*) by aerosol. Their clinical observations were similar to Hahon's. They noted a 5-day incubation period; the rash was centrifugal in distribution and appeared in an average of 7–8 days, ranging from 6 to 11 days; and the severity of the variola infection was intermediate between rabbitpox and vaccinia. Two deaths were observed in 109 monkeys infected by variola virus.

Monkeypox in the monkey has a similar clinical picture to that of smallpox in the monkey. However, in Hahon's study, the symptoms were much more severe than those of smallpox in the monkey.

McConnell et al. (1964) noted that rhesus monkeys could be protected against monkeypox by inoculation with vaccinia virus. Gipsen et al. (1967), using cynomolgus monkeys, confirmed this finding.

DISCUSSION

Reports of naturally occurring pox infections in non-human primates are few indeed and only Gispen (1949) has provided virological confirmation. Gispen's work, preceding the recognition of monkeypox virus as an entity, confirmed only that infection had been caused by a virus in the variola-vaccinia-monkeypox group. The observation that monkeypox in *Macaca irus* and *Macaca mulatta* is much more severe clinically than smallpox (Hahon, 1961; Hahon & Wilson, 1960; Westwood et al., 1966) suggests that previously reported pox disease epidemics in monkeys may have been caused by monkeypox rather than smallpox.

That no outbreaks of pox disease in monkeys in *nature* have been reported since 1936 suggests that this phenomenon must be rare indeed. Additionally the observed disappearance of human smallpox from areas with large monkey populations, e.g., Panama and Philippines, suggests that a natural animal reservoir of smallpox is most unlikely.

The absence of human infections in the various outbreaks of monkeypox suggests that man may be comparatively insusceptible to this virus. Continued studies and observations are warranted, however, since several experimental studies indicate that at least certain species of monkeys can be infected with smallpox (Hahon, 1961; Hahon & Wilson, 1960) and that infected monkeys confined in cages with other susceptibles may transmit infection (Gispen, 1949; J. Noble, personal communication, 1967).

RÉSUMÉ

Un élément important à considérer lorsqu'on examine la possibilité d'une éradication de la variole à l'échelle mondiale est l'absence de réservoir animal. Des recherches expérimentales ayant montré que le virus variolique peut atteindre des primates autres que l'homme et des études récentes faisant état d'une infection virale apparentée chez le singe, appelée « monkeypox », on a fait le point de nos connaissances sur ces deux aspects du problème.

Les rapports concernant des cas présumés de variole ou des épidémies naturelles d'infections à poxvirus chez des primates ont été examinés. Depuis 1767, sept observations de ce genre ont été enregistrées. La plus récente porte sur le cas de deux orangs-outangs qui, en 1949, ont été infectés dans un zoo d'Indonésie. On a isolé alors un virus du groupe variole-vaccine-monkeypox, mais les recherches n'ont pas été poursuivies en vue de l'identification du virus spécifique. Parmi les six

autres observations on relève deux épidémies chez des populations de primates sauvages, l'une au Brésil en 1922 et l'autre en Inde en 1936. Les quatre observations restantes étaient antérieures à notre siècle. Dans aucun cas, il n'y a eu de confirmation virologique. Si l'on considère l'extension et la prévalence de la variole dans des régions d'Asie, d'Afrique et d'Amérique à fortes populations de primates, on est frappé par la rareté relative des cas d'infection à poxvirus signalés.

Une enquête faite par l'OMS auprès de 26 instituts de biologie importants a révélé qu'au cours des dix dernières années cinq épidémies de monkeypox ont été observées dans des colonies de singes en captivité, en plus de quatre autres au sujet desquelles des rapports avaient déjà été publiés. Ces épidémies se sont produites au Danemark (une), aux Pays-Bas (deux) et aux Etats-Unis d'Amérique (six). Pour cinq d'entre elles, l'isolement du virus du monkeypox a permis de confirmer le diagnostic. Parmi les espèces de singes affectées, on peut citer notamment: *Macaca irus*, *Macaca rhesus*, *Macaca philippinensis* et entelle, originaires de l'Inde, des Philippines et de la Malaisie. L'épidémie survenue au zoo de Rotterdam a frappé de nombreuses espèces: orangs-outangs, chimpanzés, gorilles, gibbons, cercopithèques, ouistitis et sagouins. Nulle part on n'a signalé de cas d'infection humaine. Il semble donc que l'homme soit peu vulnérable au virus du monkeypox.

Depuis le début du siècle, de nombreuses études expérimentales sur les infections à poxvirus ont été effectuées sur des singes. Toutefois, les animaux n'ont été infectés que rarement par aérosols, alors que la transmission de la variole humaine semble s'opérer naturellement par cette voie. On a observé que les singes des espèces *Macaca irus* ou *M. mulatta* infectés par aérosols par le virus du monkeypox présentent une forme de maladie plus grave cliniquement, ce qui porte à croire que les épidémies d'infection à poxvirus observées antérieurement chez les singes ont été provoquées par le virus du monkeypox plutôt que par celui de la variole.

D'après ces observations, l'existence d'un réservoir animal de variole dans la nature semble peu probable. Toutefois la poursuite des études et des observations se justifie du fait que certaines espèces de primates autres que l'homme sont susceptibles de contracter l'infection variolique par voie d'aérosols et que les singes malades peuvent transmettre l'infection à des compagnons de cage appartenant à d'autres espèces réceptives.

REFERENCES

Anderson, I. (1861) *Study of fever*, London, J. Churchill, p. 180

Bleyer, J. C. (1922) *Münch. med. Wschr.*, **69**, 1009

Gispen, R. (1949) *Ned. T. Geneesk.*, **93**, 3687

Gispen, R. & Kapsenberg, J. G. (1968) *Verslagen en medelingen betseffende de Volksgezondheit*, The Hague, Gezondheidsraad (in press)

Gispen, R., Verlinde, J. D. & Zwart, P. (1967) *Arch. ges. Virusforsch.*, **21**, 205-216

Hahon, N. (1961) *J. infect. Dis.*, **109**, 294

Hahon, N. & Wilson, B. J. (1960) *Amer. J. Hyg.*, **71**, 69-80

Horgan, E. S. & Mansour, A. H. (1939) *J. Hyg. (Lond.)*, **39**, 615-637

Horgan, E. S., Haseeb, M. A. & Satti, M. H. (1948) *Brit. J. exp. Path.*, **29**, 347-355

McConnell, S. J., Herman, Y. F., Mattson, D. E. & Erickson, L. (1962) *Nature (Lond.)*, **195**, 1128-1129

McConnell, S. J., Herman, Y. F., Mattson, D. E., Huxsoll, D. L., Lang, C. M. & Yager, R. H. (1964) *Amer. J. vet. Res.*, **25**, 192

McConnell, S. J., Spertzel, R. D., Huxsoll, D. L., Elliot, L. & Yager, R. H. (1964) *J. Bact.*, **87**, 238-239

Magnus, P. von, Andersen, E. K., Petersen, K. B. & Birch-Andersen, A. (1959) *Acta path. microbiol. scand.*, **46**, 156-176

Mika, L. A. & Pirsch, J. B. (1960) *J. Bact.*, **80**, 861

Peters, J. C. (1966) *T. Diergeneesk.*, **91**, 387-391

Prier, J. E., Sauer, R. M., Malsberger, R. G. & Sillaman, J. H. (1960) *Amer. J. vet. Res.*, **21**, 381-384

Sauer, R. M., Prier, J. E., Buchanan, R. S., Creamer, A. A. & Fegley, H. C. (1960) *Amer. J. vet. Res.*, **21**, 377-380

Schmidt, M. (1870) *Zoologische Klinik. Die Krankheiten der Affen*, Berlin, A. Hirschwald, p. 97

Westwood, J. C. N., Boulter, E. A., Bowen, E. T. W. & Maber, H. B. (1966) *Brit. J. exp. Path.*, **47**, 453-465