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Five Species of Panamanian Monkeys as New Experimental Hosts for *Plasmodium simium*

Plasmodium simium was first described from *Alouatta fusca*, the howler monkey, in Brazil by Da Fonseca (1951, Mem Inst Oswaldo Cruz **49:** 543–551). The only other naturally infected simian is *Brachyteles arachnoides*, the woolly spider monkey, reported by Deane et al. (1968, Rev Inst Trop Sao Paulo **10:** 287–288). Experimental infections have been produced in four Brazilian species by Deane and co-workers as follows: *Saimiri sciureus*, the squirrel monkey (1965, Rev Paul Med **66:** 171–172); *Callithrix jacchus*, the common marmoset (1965, Rev Paul Med **66:** 174); *Lagothrix lagotricha*, the woolly monkey (1965, Rev Paul Med **66:** 363); and *Ateles paniscus*, the spider monkey (1966, Rev Paul Med **68:** 181–182). Recently, Colombian *Aotus trivirgatus*, the night monkey, was shown to be susceptible by Collins et al. (1973, J Parasitol **59:** 49–51).

During our studies in Panama, where *P. simium* has not been found, we have determined the capability of indigenous primates to support the development of the parasite. Infected blood was obtained in 1972 through the courtesy of Dr. R. Nussenzweig, New York University. Using techniques described previously by Porter and Young (1966, Mil Med **131:** 952–958), intraperitoneal trophozoite inoculations were made into the seven species of Panamanian monkeys. Recipients were unaltered, except in one instance where indicated, and were free of acquired malarial infections.

Initially, a parasite line was established in *Aotus*. Passages then were maintained in these hosts as a source of inoculum and for characterization studies. Our results for the indigenous *Aotus* were similar to the experience of Collins et al. (loc. cit.), in that *P. simium* was highly invasive. With an inoculum of $< 1 \times 10^6$ to 28×10^6 parasites, patent parasitemias developed in 18 to 21 recipients (six serial passages). Seventeen subjects succumbed during patency (between the 32nd and 87th day), in most cases with fulminating parasitemias of more than 100,000 per mm^3, and some as high as 847,190 per mm^3. Heavy infections were produced in two additional *Aotus* inoculated with blood samples that had been preserved at low temperature (−70 C) for 80 days.

Each of three Panamanian *S. sciureus* (= *oerstedii*) was susceptible after subinoculation from *Aotus*; the prepatent periods were 1 to 32 days. The parasitemias were lower (30 to 60 per mm^3) than had been reported in splenectomized *Saimiri* by Deane and Okumura (1965, loc. cit.) and by Coatney et al. (1971, The Primate Malarias, U. S. Gov. Printing Office, Washington, 366 p.), with patency ranging from 5 to 21 days. A second attack, yielding a higher count, viz., 17,660 per mm^3, occurred in one animal after a subpatent period of 6 days.

Data for the remaining monkeys tested, all representing new host systems, are detailed in Table I. Of these, *Saguinus geoffroyi* was the most receptive, showing parasitemias comparable to those in the *Aotus*. Both *Saguinus* died during patency, 8 and 5 days after maximum levels were attained ($> 200{,}000$ per mm^3). *Alouatta villosa*, the black howler monkey, experienced a moderate parasitemia of more than 40,000 per mm^3 and died 8 days after the 23-day patent period. Prepatent periods were longest in *Cebus capucinus*, the white-faced capuchin, and the two positive animals were mildly infected ($< 3{,}000$ per mm^3); parasitemias did not reappear during more than 100 days following the end of patency. The refractory *Cebus* subject (4896), the only splenectomized animal in this study, was examined 5 times per week for 52 days postinoculation. The primary attack in *Ateles fusciceps* and *A. geoffroyi*, the black and red spider monkeys, showed only low-grade parasitemias, persisting over a 3-week period. A recrudescence occurred in each of these *Ateles*, producing even lower parasitemias with shorter patent periods. After termination of the second attack, the animals remained negative for more than 200 days.

TABLE I. Plasmodium simium *infections induced in five species of Panamanian monkeys.*

Monkey No.	Parasites inoc. × 10^6	Prepatent (subpatent) period days	Patent period days	Maximum parasitemia	
				per mm^3	patent day
Saguinus geoffroyi					
6029	16	1	22*	200,360	14
6486	3	9	15*	264,650	10
Alouatta villosa					
7204	21	12	23	42,530	11
Cebus capucinus					
5294	217	23	26	2,950	15
4890	4	42	23	1,590	14
4896†	217	–	–	–	–
Ateles fusciceps					
5828	5	19	21	230	14
5828R	–	(32)	7	20	6
Ateles geoffroyi					
7097	5	13	23	220	14
7097R	–	(48)	16	30	11

* At death.
† Splenectomized prior to inoculation.
R Recrudescence.

The above findings confirm the infectiousness of *P. simium* for *Aotus* and *Saimiri*. Further, the experimental host range has been extended to the genera *Cebus* and *Saguinus* as well as to other species of *Ateles* and *Alouatta*. Our uniform success for Panamanian primate species contrasts with the restricted natural host range of this malaria and with the failure to obtain induced infections in Brazilian *Cebus* and *Callicebus* (Deane, 1967, Rev Bras Biol **27:** 213–228). Among the new hosts presented here, *Saguinus* was the most susceptible, while another species of marmoset tested by Deane (*C. jacchus*) gave only marginal parasitemias.

An interesting observation is that *P. vivax*, the human counterpart of *P. simium*, cannot be maintained in *Cebus* and *Alouatta* (Young, 1970, Lab Anim Care **20:** 361–367). The development of *P. simium* in these models therefore would appear to further differentiate *P. simium* and *P. vivax*.

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