Observations on Flea Transfer between Hosts; a Mechanism in the Spread of Bubonic Plague

A particularly important problem in plague epidemiology is concerned with the method of transfer of the disease from one rodent species to another. Since enzootic plague is known to be established in at least 15 of our western states, in western Canada, and in Mexico, the mechanism of plague transfer from wild rodents to domestic rats in the vicinity of human habitations is a particularly important question (*1*). Many investigators have suggested that the primary mechanism of plague spread is by transfer of infected fleas between hosts (*2*). Convincing circumstantial evidence that, in rural areas with a large rat population, the infection chain of "squirrel–squirrel flea–rat" may operate was obtained in studies of a plague epizootic in Ventura County, California (*3*). Although the evidence has been highly suggestive, the actual transfer of fleas from host to host has never been demonstrated.

The means for evaluating ectoparasite transfer more precisely were obtained through the development of a method for tagging fleas and other arthropods with Ce^{144} (*4*). By use of the California vole (*Microtus californicus*), domestic rats (*Rattus norvegicus*) and radioactively tagged wild rodent fleas (*Malaraeus telchinum*), a preliminary study of flea transfer was conducted in experimental plots simulating field conditions. These plots were enclosed by steel screens and provided soil and native grasses for the establishment of the rodents. In one type of experiment, male and female *Microtus* were toe-clipped for identification and allowed to establish nests; then tagged fleas were placed on certain individuals. Traps were set each day, and the captured animals were lightly anesthetized. The fleas were removed, and checked for radioactivity, and then returned to the hosts. In another experiment, three rats were maintained in a closure adjacent to three *Microtus* harboring tagged fleas, or the rats were allowed to enter the vole enclosure after the wild rodents had been killed or while they were alive. In all cases, a survey meter, Nuclear model 2612 equipped with a mica end-window probe, was used to scan the animals and fleas removed from them. The radioactivity of each flea was checked at the end of each trial with a RIDL scaler equipped with an end-window counter, Scott type.

Table 1 summarizes typical data on the movement of tagged fleas between individual *Microtus*. It should be noted that fleas transferred between animals, were found in nests, and were eaten by the animals, as was shown by radioactive feces. Thirty to sixty percent of the fleas were recovered from *Microtus* and their nests after periods ranging from 13 to 21 days.

The movement of radioactively tagged wild rodent fleas from the voles to the rats may be summarized as follows: 30 tagged fleas were introduced via the *Microtus*; while the *Microtus* were alive, none of these were found on the separated rats; after the *Microtus* were killed by snap-trapping, seven flea transfers were noted when the rats had entered the area with the dead voles; no transfers were noted on three new *Microtus* placed in the enclosure after the rats were again separated; 30 tagged fleas were placed on the new *Microtus*, and 12 transfers to rats were noted when the rats were allowed in the area with the live voles. Of the 60 fleas placed on the *Microtus*, none was found in *Microtus* nests, and 27 were recovered from the rats' nests. Radioactivity was found in *Microtus* feces twice, once in rat feces. Of the total fleas added, 49, or 81.6 percent, were accounted for during a period of 56 days. It should be noted that over 50 percent of the fleas accounted for were recovered between days 50 and 56. The fleas showed an initial average count of $(6.2 \text{ to } 8.5) \times 10^2$ counts per flea per minute, and after 56 days, $(3.6 \text{ to } 5.1) \times 10^2$ counts per flea per minute.

Under actual plague epizootic conditions, the coexistence of *Microtus*, *Malaraeus*, and *Rattus* has been postulated to be a significant relationship in a complex ecological situation in which other flea and rodent species are involved (*5*). Further studies on flea transfer under actual field conditions are being planned to confirm and extend the obserevations reported here (*6*).

Table 1. Movement of radioactively tagged wild rodent fleas, *Malaraeus telchinum*, between one male and two female voles, *Microtus californicus*.

Trial No.	No. fleas added	Sex of host	Days of trial	No. flea transfers	No. times radioactive feces found	No. fleas recovered		Percent fleas accounted for
						Animal	Nest	
1	40	M	18	21	4	11	16	67
2	10	F	21	9	not checked	5	no nest	50
3	10	F	18	21	not checked	3	no nest	30
4	12 ♂	F	6	8	1	0 ♂	0 ♂	36
	13 ♀	F				4 ♀	4 ♀	
5	15 ♂	F	13	40	not checked	2 ♂	3 ♂	62
	11 ♀	F				6 ♀	5 ♀	

W. V. Hartwell
S. F. Quan
Communicable Disease Center, U.S. Public Health Service, San Francisco, California
K. G. Scott
Department of Radiology, University of California, School of Medicine, San Francisco
L. Kartman
Communicable Disease Center, U.S. Public Health Service, San Francisco

References and Notes

1. A discussion of flea transfer in plague ecology is given in L. Kartman, F. M. Prince, S. F. Quan, and H. E. Stark, *Ann. N.Y. Acad. Sci.*, in press. A review of the literature may be found in R. Pollitzer, *World Health Organization Monogr. No. 22* (1954).
2. G. W. McCoy and M. B. Mitzmain, *Public Health Repts.* 24, 1013 (1909); W. C. Jacobsen, *Calif. State Comm. Hort. Bull.* 7, 721 (1918); W. M. Dickie, *Proc. Conf. State and Provincial Health Authorities N. Am.* (1926), p. 30; F. M. Prince, *Public Health Repts.* 58, 700 (1943).
3. K. F. Meyer and R. Holdenried, *Puerto Rico J. Public Health Trop. Med.* 24, 201 (1949).
4. S. F. Quan *et al.*, *Trans. Roy. Soc. Trop. Med. Hyg.* 51, 87 (1957).
5. V. I. Miles, A. R. Kinney, H. E. Stark, *Am. J. Trop. Med. Hyg.* 6, 752 (1957); L. Kartman, V. I. Miles, F. M. Prince, *Am. J. Trop. Med. Hyg.*, in press.
6. Acknowledgment is made to the following for aid and advice in these experiments: F. M. Prince, A. R. Kinney, R. L. Martin, and H. E. Stark.

18 November 1957

Presence of Polyamines in Certain Bacterial Viruses

Recent studies from this and other laboratories have shown the wide distribution of the polyamines putrescine [$NH_2(CH_2)_4NH_2$], spermidine [$NH_2(CH_2)_3NH(CH_2)_4NH_2$], and spermine [$NH_2(CH_2)_3NH(CH_2)_4NH(CH_2)_3NH_2$] in nature (*1–3*). Little is known of their function, but their importance is implied by their roles as growth factors for several microorganisms (*4*) and as substrates for amine oxidases (*5*), and by their pharmacological effects (*1*). A possible functional connection with nucleic acids is suggested by the in vitro affinity of spermidine and spermine for nucleic acids and by the recovery of a considerable quantity of these bases from the nuclear fraction of liver cells (*3*). The studies on polyamines and the unanswered question about what compounds neutralize the negatively charged phosphate groups of the deoxyribonucleic acid (DNA) in bacteriophage (*6*) led to the present study of the polyamine content of phage.

Putrescine and spermidine are present in phage T_4 of *Escherichia coli* B in quantities sufficient to neutralize much