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Differential Signs of Plague in Young and Old California Ground Squirrels (*Spermophilus beecheyi*)

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California ground squirrels have been the source of many human cases of plague. The peak prevalence of plague in these squirrels usually occurs soon after the young of the year appear above ground, suggesting a high susceptibility in many of the young. Nevertheless, young squirrels exhibit high variability in their susceptibility to plague (Williams et al., 1979, *J. Infect. Dis.* 140: 618–621). Susceptibility to plague is greater in young than in old Asian ground squirrels, *Citellus pygmaeus* (Tinker and Kalabukhov, 1934, *Vestn. Mikrobiol. Epidemiol. Parazitol.* 13: 299–303), *C. fulvus* and *C. relictus* (Lavrent'yev, 1963, *In Materialy Nauchnoy Konferentsii po Prirodnoy Ochagovosti i Profilaktike Chumy*, Afanas'yeva and Khurtselevskiy (eds.), Alma Ata, Kazakhstan, USSR, pp. 130–131). Studies done 40 yr ago with *S. beecheyi* considered age-related differences in susceptibility, but the data obtained were not convincing (Meyer, 1942, *In Medico-Surgical Tributes to Harold Brunn*, Univ. California Press, Berkeley, California, pp. 307–316). In recent studies, reported here, pathological signs of plague observed in young and old squirrels suggested that changes in susceptibility with age may also occur in *S. beecheyi*.

Forty-six 3-mo-old *S. beecheyi* were collected in Monterey County, California, conditioned to the laboratory over 2 mo and inoculated with various doses of *Yersinia pestis*, as previously reported (Williams et al., 1979, op. cit.). Another six squirrels, collected with the others, were maintained in separate cages for 21 mo, until 24 mo of age, and then inoculated in the same manner. Squirrels were seronegative for antibody to *Y. pestis* when collected and when inoculated with *Y. pestis*. Virulent *Y. pestis* of the California strain 761000, orig-

inally isolated from a California ground squirrel, were cultured at 25 C and then injected subcutaneously on the abdomen. Squirrels that died were examined at necropsy, and specimens from blood, spleen, abscesses and buboes were streaked on blood agar to confirm infection by the isolation of *Y. pestis*.

There was a clear relationship between number of *Y. pestis* inoculated into 5-mo-old squirrels and the mortality produced (Table 1). Mortality was somewhat less for 5-mo-old than for 24-mo-old squirrels that received similar doses of *Y. pestis* (e.g., 60,000–600,000 bacilli), but the difference was not significant by chi-square test ($\chi^2 = 0.64$, $df = 1$, $P > 0.05$). However, young animals usually died more rapidly. While 80% (4/5) of old squirrels died at 9–11 days after inoculation, 83% (5/6) of young squirrels died at 3–7 days postinoculation. Bacteremia, demonstrated by isolation of *Y. pestis* from heartblood, was present in all squirrels that died, regardless of age.

Five young squirrels were bleeding from the nose when they died. Agonal nosebleeding was not indicative of rapid death, as the time to death for squirrels with nosebleeds ranged 3–14 days postinoculation (average = 8.8 days). Nosebleeding was especially common in squirrels that received moderate infective doses of 600–6,000 *Y. pestis*.

All old squirrels that died of plague had buboes at the site of inoculation. Some were as large as 3 cm in diameter. Young animals never developed buboes. Abscesses of the liver and spleen were observed in all (4/4) old and 43% (3/7) of young animals that survived 9 or more days after inoculation before dying of plague. *Yersinia pestis* was isolated from all buboes, abscesses and spleens. Buboes and nosebleeding were not observed in squirrels that survived.

A statistically significant difference in mortalities from plague in young and old squirrels inoculated with similar quantities of *Y. pestis*

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TABLE 1. Susceptibility of California ground squirrels to plague and pathological signs of disease.

	Number of <i>Y. pestis</i> inoculated			
	Squirrels 5 mo of age			Squirrels 24 mo of age
	6-60	600-6,000	60,000-600,000	100,000
Mortality (no. dead/no. inoculated)	17% (3/18)	39% (7/18)	60% (6/10)	83% (5/6)
Average day of death	9.7	9.7	5.7	9.4
Bubo at site of inoculation*	0% (0/3)	0% (0/7)	0% (0/6)	100% (5/5)
Abscess in spleen or liver*	33% (1/3)	14% (1/7)	17% (1/6)	80% (4/5)
Agonal nosebleed*	0% (0/3)	57% (4/7)	17% (1/6)	0% (0/5)

* Parentheses give number presenting over number examined. The squirrels examined were those that died of plague.

was not demonstrated in this study. Admittedly, only small numbers of squirrels could be tested, but earlier investigations by Meyer (1942, op. cit.), in which hundreds of California ground squirrels were tested, also failed to demonstrate such a difference. However, old squirrels displayed a greater ability to localize infection in our study, as evidenced by a high frequency of abscess formation. This ability was insufficient to overcome disease by fully virulent *Y. pestis*, although death was delayed in most old squirrels. Perhaps old squirrels might be more capable than young animals of surviving inocu-

lations with lesser doses of virulent *Y. pestis* or infections with strains of reduced virulence (Cavanaugh and Williams, 1980, *In Fleas*, Traub and Starcke (eds.), Balkema, Rotterdam, Netherlands, pp. 245-256).

Young squirrels present a great threat of contagion because of agonal nosebleeding during bacteremia. Such animals, and their carcasses, are especially hazardous to persons and wild or domestic animals that have contact with them. Agonal nosebleeding in old squirrels, while not observed in this study, remains a possibility at lower infective doses of *Y. pestis*.

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Necrobacillosis in Wildebeest Calves

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Rosen (1981, *In Infectious Diseases of Wild Mammals*, 2nd Ed., Davis, Karstad and Trainer (eds.), Iowa State Univ. Press, Ames, Iowa, pp. 332-338) described necrobacillosis as an infectious disease caused by *Fusobacterium necrophorum* characterized by a purulent, hoof necrosis in wild ruminants. This condition is better referred to as "foot abscesses" rather than "hoof rot," a condition normally associated with a distinctly separate disease. Drager (1975, *Trop.*

Anim. Prod. 7: 200) diagnosed necrobacillosis in gemsbok (*Oryx gazella*) in the Kalahari Desert, Botswana and it has been implicated as an infection in wildebeest (*Connochaetes taurinus*) in the Serengeti National Park (Talbot and Talbot, 1963, *Wildl. Monog.* 12: 1-88; Mustafa, 1973, *Coll. Afr. Wildl. Manage.*, Mweka, Tanzania, 126 pp.).

Stobart (1970, *Tanz. Game Div. Rep. Dar-es-Salaam, Tanzania*, 30 pp.) made reference to a severe outbreak of a condition in wildebeest calves that answers the description of the foot abscess form of necrobacillosis. This occurred during the wet season near the Miombo Research Center in the eastern sector of the Selous

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