lymphocytes bear opiate receptor sites for β-endorphin and for some synthetic and natural analogues, and support the concept that opioids can be involved in the regulation of lymphocyte activity[10,19]. This finding, and the well-known existence of a subpopulation of human T lymphocytes which react with an heteroantiserum to human brain[20], provides further evidence of close links between the immune system and the central nervous system.

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Potential for rat plague from nonencapsulated variants of the plague bacillus (*Yersinia pestis*)

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Summary. Potentials for oral and flea-borne transmission of nonencapsulated *Y.pestis* were demonstrated when 45% of rats that consumed infected meat died of plague and 22% of the rats that died of plague had bacteremia.

Nonencapsulated (F1−) *Yersinia pestis* are plague bacilli that lack the ability to produce an envelope containing fraction 1 virulence antigen. Nevertheless, infections with certain F1− *Y.pestis* can cause fatal disease in man[2] and laboratory mice[3]. However, laboratory rats that have a high susceptibility to plague from encapsulated (F1+) *Y.pestis* have appeared to be resistant to fulminating disease from F1− organisms, although chronic infections with F1− bacilli occur. As outbreaks of plague in human populations are frequently associated with rat plague, any resistance to disease in rats is significant because it reduces the danger of plague for humans. Resistance results in fewer rats dying and, thus, fewer infected carcasses and hostless fleas to transmit the disease to people. To confirm such resistance in rats, F1− *Y.pestis* of high virulence for mice were inoculated into rats. In addition, the possibility that large infective doses of F1− bacilli might overcome any resistance to disease was examined by feeding infected material to rats.

Materials and methods. F1− *Y.pestis* were isolated on blood agar from the abdominal bubo of a vaccinated rat that died 541 days after challenge with the virulent F1+ *Y.pestis* strain 195/P[4]. Single colony picks were examined on congo red-agar[5], pesticin 1 agar[6], and magnesium oxalate agar[7]. A clone demonstrating pigmentation, pesticin 1 and calcium dependence, all indicators of virulence, was chosen for inoculation into laboratory mice (ICR strain) and rats (Wistar strain)[8]. This clone, strain CPS-2a, was cultured at 25 °C in 2% peptone broth, diluted in the same medium, and inoculated s.c. into animals. Data on the virulence of strain CPS-2a were compared to data for the F1− strain CPS-1, studied previously[3], and for the F1+ *Y.pestis* strain 195/P.

In another experiment, carcasses of mice that had died from infection with F1− *Y.pestis* strain CPS-2a were fed to 20 rats. After several days without food, each rat was given 1 mouse carcass. Rats were moved into clean cages 36 h later and fed their normal laboratory chow. Rats that died were necropsied. Isolation from the spleen, on blood agar, was attempted to prove plague infection. Bacteremia was confirmed by isolation of bacilli from blood.

Results. Strain CPS-2a was of considerably greater virulence for laboratory rodents than the F1− *Y.pestis* strain CPS-1 (table 1). Strain CPS-2a was almost as lethal for mice as the typical F1+ *Y.pestis* strain 195/P. However, inoculation of moderate infective doses of strain CPS-2a killed only 2 rats (20%). F1− *Y.pestis* were isolated from the spleens of both. All rats fed carcasses of infected mice appeared sick 4–5 days later, and

Table 1. Virulence of F1− *Yersinia pestis* for laboratory rodents

	F1− *Y.pestis* strain CPS-1	F1− *Y.pestis* strain CPS-2a	F1+ *Y.pestis* strain 195/P
No. bacilli per mouse LD_{50}, 2 weeks post inoculation	> 502,000	60	35
No. bacilli inoculated into rats	50,000–600,000	190–1,900	1,450
No. rats dead/no. inoculated, 2 weeks post inoculation	0/8	2/10	10/10

Table 2. Oral transmission of F1− *Yersinia pestis* strain CPS-2a to rats

No. days after consuming infected mouse carcass	No. rats dead	No. rats with *Y. pestis* infection	No. rats with bacteremia	No. rats with infected spleen	No. rats with infected bubo	Phenotype of *Y.pestis* isolated
4	5	5	1	5	0	F1−
5	4	3	1	3	0	F1−
6	1	0	0	0	0	
7	1	1	0	1	0	F1−
137	1	1	0	0	1	F1−
168–369	8	0	0	0	0	
Total	20	10	2	9	1	

9 rats (45%) died of acute plague (table 2). Two rats developed bacteremia. Another rat, that survived 137 days, was found at necropsy to have a pleural bubo situated anterior to the heart that measured 0.5 cm in diameter. The bubo contained viable F1− *Y.pestis*.

Discussion. These experiments confirm earlier evidence[3] that rats are more resistant than mice to disease from F1− plague bacilli. However, resistance to disease can be overcome in many rats by the oral transmission of large infective doses of F1− *Y.pestis*. Wild rats are omnivorous and will consume corpses[9]. Thus, the experimental data indicate that a potential for rat plague from F1− organisms exists, especially via the consumption of infected material. Agonal bacteremia occurs in some rats, as in most mice[3], so flea-borne transmission of F1− *Y.pestis* also should be possible. All F1− strains we have examined exhibit the complex of pesticin-coagulase-fibrinolytic factor that is required for maintaining *Y.pestis* infections in fleas and for establishing vector capacity[10]. However, fleas frequently transmit moderate infective doses of bacilli[11], which many rats would resist. Consequently, disease from F1− *Y.pestis* may occur only infrequently in wild rats, and the probabilities for human infection may be low. Perhaps this explains why just one human case of plague from naturally-acquired F1− *Y.pestis* has been documented to date[2].

1 The views of the authors do not purport to reflect the position of the Department of the Army or the Department of Defense (para 4–3, AR 360-5).
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Effect of 5-hydroxytryptamine antibodies on pigment migration in the erythrophores of the fiddler crab, *Uca pugilator:* Further evidence for 5-hydroxytryptamine as a neurotransmitter that stimulates release of red pigment-dispersing hormone

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Summary. 5-Hydroxytryptamine (5-HT) antibodies inhibit red pigment dispersion in the fiddler crab, *Uca pugilator*. This observation supports the hypothesis that 5-HT stimulates release of red pigment-dispersing hormone.

Centrifugal translocation of the pigment in the erythrophores of the fiddler crab, *Uca pugilator*, is mediated by a red pigment-dispersing hormone (RPDH)[1]. 5-Hydroxytryptamine (5-HT) also produces red pigment dispersion when injected into fiddler crabs, but unlike RPDH, has no effect on the erythrophores of isolated legs[2]. 5-HT, which is present in the central nervous system of the fiddler crab[3], thus may act as a neurotransmitter stimulating RPDH release in the fiddler crab. Data obtained using a variety of pharmacological agents known to affect 5-HT neurotransmission, at least in mammals, have strengthened the putative role of 5-HT as a neurotransmitter eliciting release of RPDH in *Uca pugilator*[4–6]. On the other hand, dopamine appears to be the neurotransmitter stimulating release of the RPDH antagonist, the red pigment-concentrating hormone (RPCH)[7].

The availability of antibodies against 5-HT has provided a powerful tool to demonstrate its presence. 5-HT antibodies should react with 5-HT in *Uca pugilator* and thereby decrease the amount available to stimulate RPDH release. In the present study 5-HT antibodies were injected into fiddler crabs either maintained on a white or a black background, shifted from a white to a black background or shifted from a black to a white background. The effects of the antibodies on the degree of red pigment dispersion were then observed. A white background fosters red pigment concentration whereas a black background fosters red pigment dispersion[1].

Materials and methods. Intact adult male fiddler crabs, *Uca pugilator*, from the vicinity of Panacea, FL (Gulf Specimen Co.) were used. The crabs were exposed to an illumination of 1190 lx during the experiments, which were performed at 24 °C. The erythrophores seen through the cuticle on the anteroventral surface of the second walking leg on the right side