Plague, camels, and lice

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In PNAS, the paper by Namouchi et al. (1) suggests that there were no reservoirs of plague in Europe in the Middle Ages, but rather multiple reintroductions. This study may be completed by reporting several works poorly cited in literature which add to our comprehension of plague transmission. It is clear that plague pandemics resulted from the introduction of infected patients (or infected rats by boats) in Marseilles, Genoa, and Venice. On the other hand, we now know that Bactrian camels and dromedaries are likely to be carriers of *Yersinia pestis* (2), and there are cases of plague contracted by the consumption of camels. Historical sources attest to the consumption of camels since the Hellenistic period in Eurasia. This element is probably important in the circulation of the plague, as with cholera, and also explains that what appears to be the fur route is actually the Silk Road that camels used. This leaves the question of the blazing speed of the Black Death epidemic unsolved, especially considering that there is no stable reservoir. This was controversial in our first description of the discovery of *Y. pestis* in Black Death (3). It is clear that plague epidemics have not been described in a context of massive epizootic disease, including rats (4). At the time when most city dwellers were carriers of ectoparasites (fleas and lice), the latter played a considerable role in spreading from sporadic cases. Index cases may have been imported from endemic countries. Indeed, as early as the end of the 18th century, the role of lice was suspected during the outbreak of the plague in Moscow in 1771 (4). In addition, the infection of head lice by *Y. pestis* was reported in 1903 and 1916, that of body lice in 1914, and the role of lice as vector of plague was reported experimentally in 1935 by John D. Long (5). Blanc and Baltazard (6) demonstrated during a small outbreak the presence of *Y. pestis* in body lice, and we recently highlighted *Y. pestis* in lice in an endemic area in Congo (7). We also set up an experimental model of lice infection that suggests that pandemics could take place only thanks to transmission by ectoparasites (8). In accordance with the modeling of different transmission patterns on nine plague epidemics in Europe between the 14th and the 19th century, the only possible transmission of *Y. pestis* in a context of mass mortality is that of human ectoparasites (9). It should be noted that no zoonosis is capable of determining epidemics of this nature and that the human-to-human transmission by the respiratory route of plague is too weak to explain an epidemic (10). Human ectoparasites, then, spread the disease with a magnitude already observed for louse-borne, relapsing fever typhus or trench fever. In practice, it is likely that plague pandemics journeyed using camels and boats and spread between humans thanks to human ectoparasites.

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