Fleas: circus artistes or mass murderers?

A valiant flea that dares eat his breakfast
on the lip of a lion (Shakespeare; *Henry V,* II.iii)

Over the centuries fleas have not only pricked and annoyed people but also stimulated scientific curiosity. Aristotle believed that fleas originated from excrement. The Romans thought they were animated dust or dirt. For some time fleas were used for human amusements, 'performing' in so-called flea circuses (see Box 1 on p. 26). But they are not only amusing, they transmit some nasty diseases — one of the reasons for the scientific interest. This interest has yielded a lot of information on disease transmission and some fascinating biology.

Main characteristics of fleas

The fleas constitute an isolated order of insects, Siphonaptera. There are over 2000 species of fleas recognised worldwide, of which 68 live in the British Isles. They are small wingless creatures which cannot be mistaken for any other insects. Their bodies are flattened from side to side and covered with stiff hairs that point backwards (see Figure 1). This body form helps the flea to slide easily through the host's hair. All fleas are equipped with tubular sucking mouthparts. Their eyes are poorly developed or absent, depending on the species. Each foot has a pair of strong claws and two rows of stiff bristles, forming an effective clinging mechanism. Other 'anchoring' body structures are the combs of rigid spines found on the head and body (see Figure 1).

But the real hallmark of fleas is their jumping ability. These flightless insects can jump 100 times their own length. Even more surprising is that fleas can make these jumps repeatedly, apparently without tiring. The tropical rat flea can jump repeatedly 600 times an hour for 3 days. The main propulsion comes from the hind legs. However, the flea's astonishing jumping ability is not accomplished by muscles alone. It is greatly aided by the presence of resilin, a rubber-like protein, in the thorax (see Figure 1). When the flea's hind legs are

The biological sciences play an important part in our everyday lives. *Interface* deals with the ways in which biological knowledge is being used in our society, for both the individual and the community.

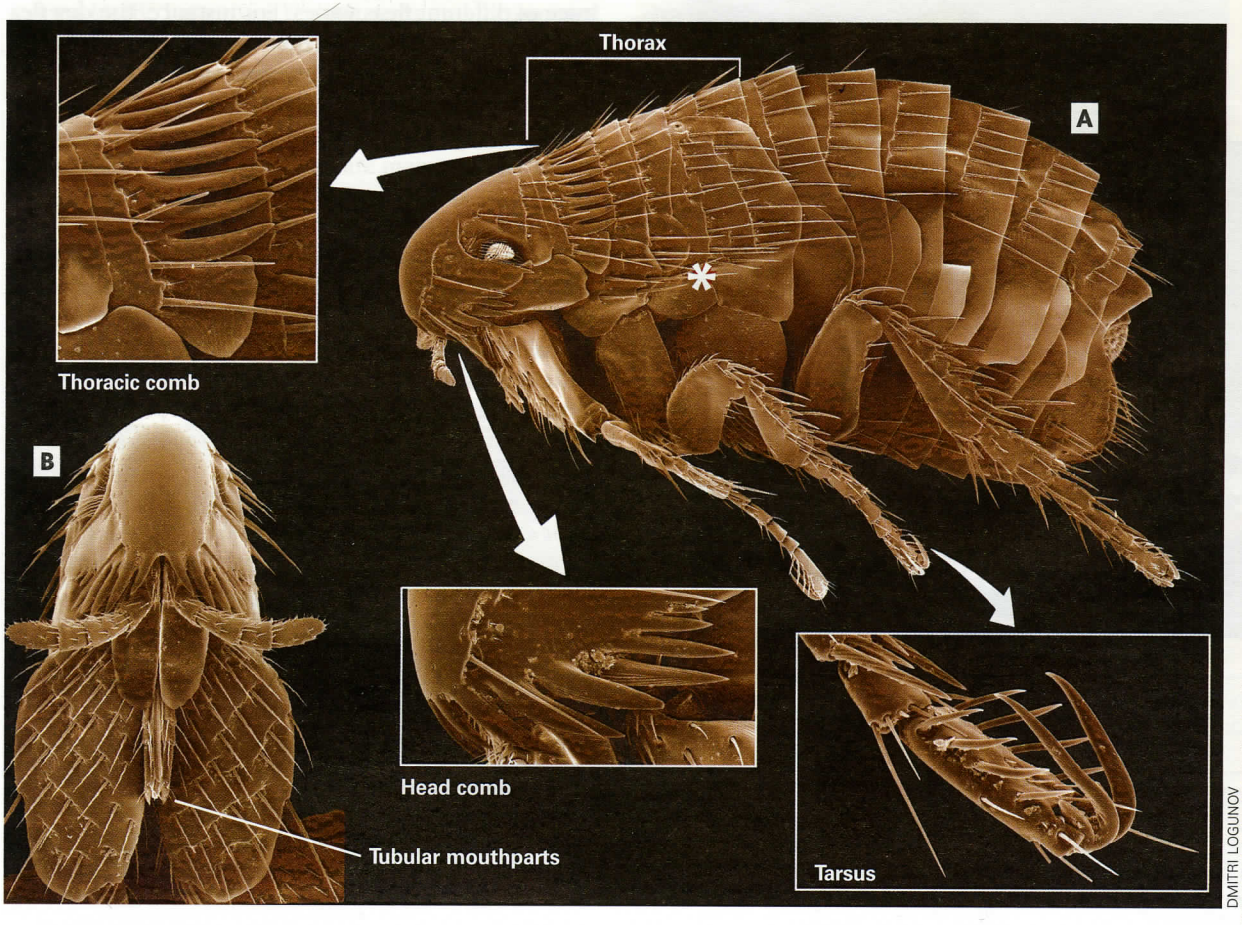

Figure 1 **Scanning electron micrograph of the female cat flea. (A) Lateral view (×50), (B) front view of the flea's head showing the tubular mouthparts (×100). The asterisk in (A) marks the area of the thorax containing resilin.**

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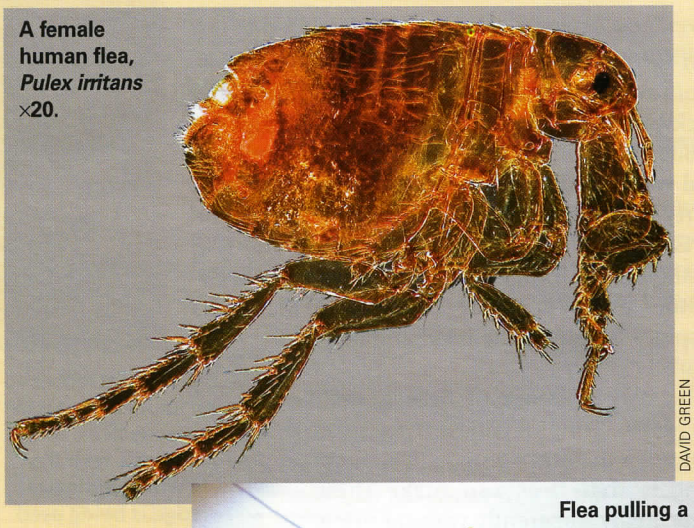
BOX 1 Performing fleas

Flea circuses were sideshow attractions in which fleas were forced to 'act' with miniature tools within small housings. The human flea was the only species used in these shows. One of the last British flea circuses was in Manchester's Bellevue Park and was closed in 1976. However, there are still a few private shows in the USA.



A female human flea, *Pulex irritans* ×20.

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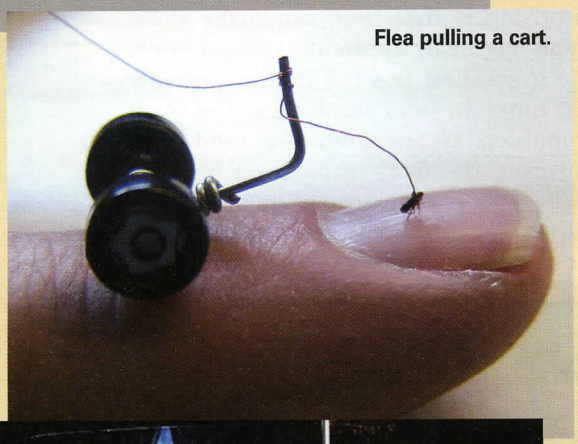

Flea pulling a cart.

WALT NOON

A complete indoor flea circus.

WALT NOON

latched in a 'cocked' position, a cap of resilin is squeezed and compressed between the cocked leg and the plate of the thorax. Then, at the right moment, the flea releases the catches. The resilin snaps back to its original size in a millisecond, like an uncoiling spring, and exerts a sharp downward force on tendons connected to the hind legs, so launching the flea into the air.

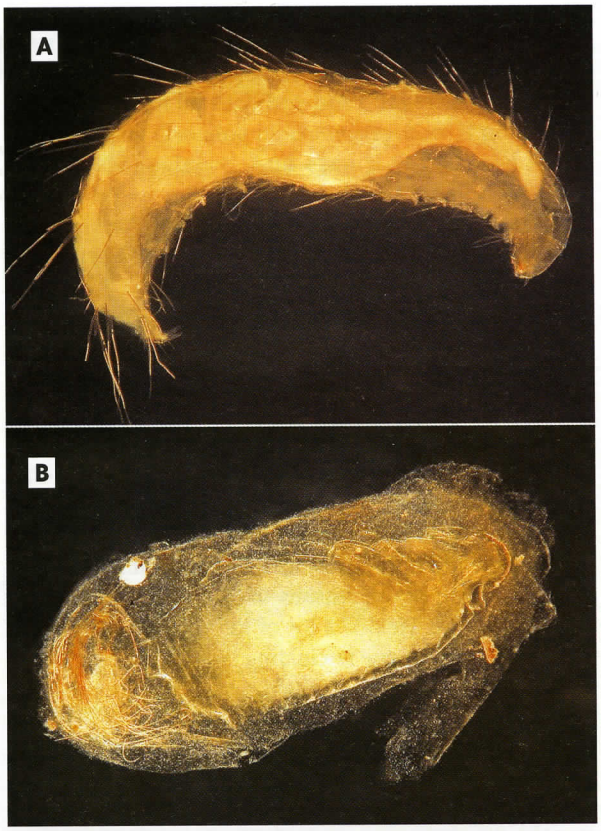

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Figure 2 **(A) A typical worm-like flea larva and (B) a pupa inside a cocoon.**

Fleas jump in order to attack their hosts. The jump is also an effective means of escape. The jumping performance of different fleas varies. For instance, the dog flea can jump some 10 cm further than the cat flea. Male fleas are normally smaller and they jump shorter distances than females. Certain species, such as mole or bat fleas, cannot jump at all and are reduced to walking or crawling.

Natural history

Fleas are **ectoparasites** that feed on the blood of warm-blooded animals. Over 94% of the known species are parasites on mammals, particularly rodents (75%), and 5% of them live on birds. The life cycle of a flea, which takes place in the host's dwelling, has four phases — egg, larva, pupa and adult. Fleas spend only a part of their life on their host, particularly as adults, to feed (except the so-called sedentary fleas — see Box 2). Worm-like flea larvae (see Figure 2) are free-living feeders that pass their entire pre-adult life off the body of the host. They do not suck blood but feed on organic debris present in the host's dwelling and also on granules of dried, undigested blood excreted by adult fleas. Such a lifestyle alternation between free and parasitic existence is called phase parasitism.

Development through three larval stages can take 2–3 weeks. Then the larva spins a cocoon and pupates inside it. The pupal stage lasts 1–2 weeks depending on humidity and temperature. The newly developed adult flea can remain alive but inactive within the cocoon for over a year. The flea requires a stimulus such as vibration, warmth or other signs of a nearby host to induce

TERMS explained

Ectoparasite An external parasite on larger animals.

Insecticide A chemical that kills insects.

Murine Relating to mice or rats.

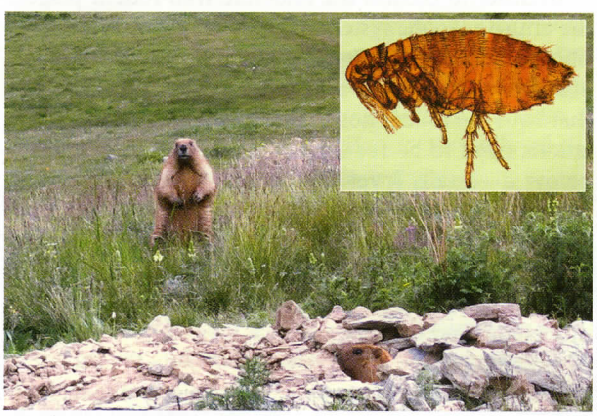
Pandemic An epidemic of worldwide scale.

it to leave the cocoon. As a consequence, the first animal to enter a dwelling may be suddenly attacked by hordes of hungry fleas. This remarkable ability of fleas — to survive for long periods without food — appears to be an adaptation for inhabiting seasonal dwellings of potential hosts. Adult fleas usually live for just one season, although they have been known to overwinter on a host (e.g. a marmot).

Fleas are not specific in their feeding and can attack various hosts. For instance, the cat flea (*Ctenocephalides felis*) feeds not only on cats but can also feed on dogs, goats, sheep, cattle and many others, including humans. In nature, however, fleas tend to be dwelling-specific and therefore can attack a limited number of potential hosts.

Fleas and plague

Flea bites are a well-known source of irritation, giving rise to allergic skin reactions and anaemia. But the relations between humans and fleas are particularly darkened by the fact that fleas can transmit pathogens that cause various human and animal diseases (see Table 1). The most important of these diseases is bubonic plague (see Box 3 on p. 28). It is a rodent-associated disease caused by the bacterium *Yersinia pestis* and transmitted to humans exclusively by the bite of rodent fleas. The original home of the disease is thought to be the arid and mountain regions of central and south Asia, known as primary natural plague foci. In these regions, plague bacteria persist indefinitely and are maintained in populations of certain rodents, such as marmots, gerbils and voles (see Figure 3). These rodents are called the primary hosts — they serve as the major natural reservoir of plague. Circulation of the plague bacteria between the primary hosts (the rodents) and their fleas, known as the enzootic cycle (see Figure 4 on p. 28), is crucial for the long-term maintenance of plague. In this

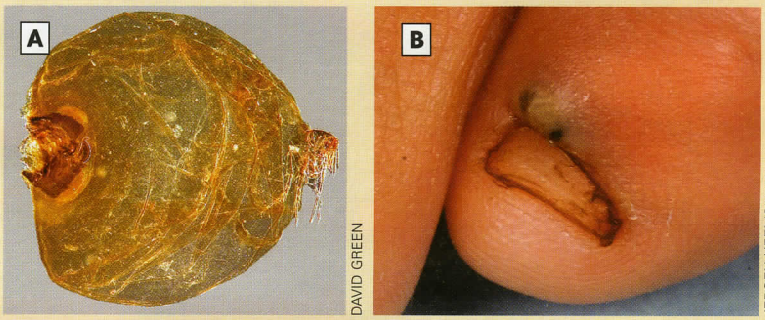


NATALIA LOPATINA (MARMOT) & SERGEI MEDVEDEV (FLEA)

Figure 3 **The grey marmot (*Marmota baibacina*) and (inset) its specific flea (*Oropsylla silantiewi*) on the mountain Altai, Ukok Plateau.**

BOX 2 Fleas with the sedentary lifestyle

Jiggers, or sand fleas, occur in tropical regions. They do not transmit any disease to humans but are a nuisance because pregnant females burrow into the host's skin, where they develop, produce eggs and eventually die. Neglected jigger lesions often become infected, and can cause severe complications — for instance, tetanus.



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(A) Fully expanded female of the jigger flea removed from under the skin (×8), and (B) a lesion on a toe caused by the jigger burrowed into the skin.

form, the disease is of little importance to humans, but occasionally trappers and hunters catch it when handling infected wild animals.

The natural cycle of transmission of the plague bacterium may include some incidental hosts, such as foxes, camels etc. Various species of fleas bite these animals and can lead to plague spreading to these secondary hosts and the so-called epizootic cycles of plague circulation (see Figure 4). Secondary hosts and their fleas cannot maintain the plague bacteria in the absence of the primary hosts but might help considerably in spreading the disease. If the disease has been transmitted to rats living in close association with people, the result can be an urban plague. The plague bacteria are maintained in the rat population by several fleas, primarily by the tropical rat flea, the principal transmitter of both plague and another disease, **murine**

Table 1 **Some pathogens transmitted by fleas (simplified from Bibikova, 1977)**

Disease and pathogen	Survival and reproduction in flea's gut	Method of transmission*
Tularemia — bacterium *Francisella tularensis*	Several days; not reproduced	Mechanical inoculation
Myxomatosis of rabbits — virus *Fibromavirus myxomathosis*	Up to 100 days; not reproduced	Mechanical inoculation
Murine typhus — bacterium *Rickettsia typhi*	Throughout lifetime; reproduced	Specific contamination
Salmonellosis — two kinds of *Salmonella* bacterium	Up to 40 days; reproduced	Specific inoculation and specific contamination
Plague — bacterium *Yersinia pestis*	Several months to over a year; reproduced	Specific inoculation and specific contamination

* Mechanical inoculation is via contaminated mouthparts, specific inoculation is via bloodsucking and regurgitating, specific contamination is via flea's faeces.

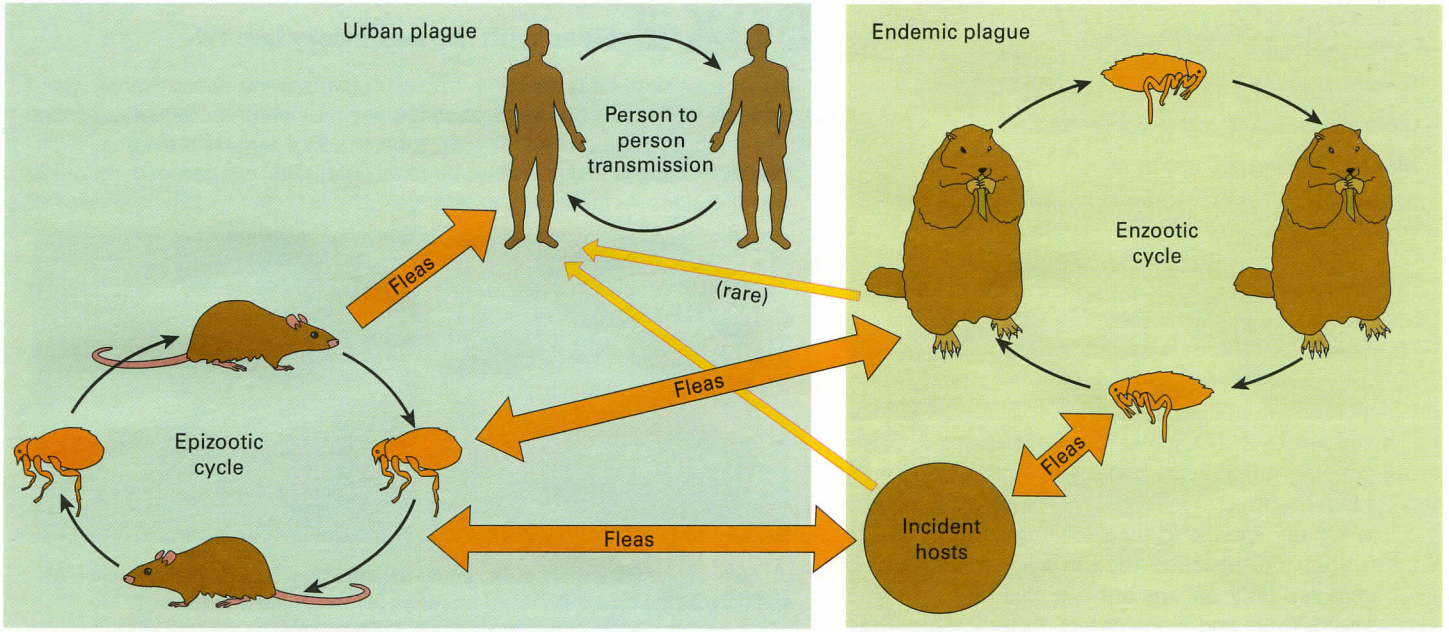

Figure 4 **Natural cycles of plague (modified from Gade and Kosoy, 2004). Enzootic cycle: marmot and its flea; epizootic cycle: black rat (*Rattus rattus*) and tropical rat flea.**

BOX 3 Ravages of bubonic plague

Bubonic plague is an acute bacterial fever, fatal to humans if untreated. It has caused three major **pandemics**: Justinian's plague in the sixth century, in which about 25 million people died, the Black Death in the fourteenth century which killed 1.5 million in England and 75 million worldwide, and the Third Pandemic that started in 1894 with 12 million deaths in China and India alone. It has been said that fleas have unwittingly killed more men than were lost in wars. Plague still occurs in modern times. Between 1987 and 2001, outbreaks involving hundreds of cases were registered in 14 countries.

typhus. The plague-infected rats rapidly develop an acute form of the disease and die. On death of the rats, the infected fleas leave their normal hosts and attack humans, which may well result in the development of a plague epidemic.

Fleas are active transmitters of plague. The plague bacteria proliferate in the flea's gut where they produce a gelatinous plug, blocking the gut partially or completely. The flea is then unable to swallow its next meal of blood and begins to starve. As it gets hungrier, it desperately attempts to bite and feed again, often seeking a new rat or human host. The blood is sucked up to the blocking plug and, after many futile efforts, is regurgitated back into the wound. As the regurgitated blood is heavily infected with pathogens reproduced inside the flea's gut, a new host becomes effectively infected with plague.

Further reading

Lehane, B. (1969) *The Compleat Flea*, John Murray.

Moor, C. (1997) *Fleas and Ticks*, online at: **www.k9web.com/dog-faqs/fleas-ticks.html**

Rothschild, M., Schlein, Y., Parker, K., Neville, C. and Sternberg, S. (1973) 'The flying leap of the flea', *Scientific American*, Vol. 229, pp. 92–100.

Control

The control measures necessary to deal with domestic fleas are different from those needed to deal with rodent fleas in the wild. A great variety of commercial products, such as powders, sprays and ointments, exist for the treatment of domesticated animals. Various **insecticides** are used to eliminate domestic fleas from them. However, a consistent control of their infestations can only be achieved through the application of the systemically acting chemicals known as insect growth regulators. These agents, for example diflubenzuron, prevent egg-to-adult development of fleas and seem to be the most efficient means of controlling their infestation in household and yard conditions.

In order to control the endemic wild rodent plague, the entire enzootic system has to be targeted. It is impossible to eradicate plague completely, but we can develop effective methods for plague prevention. This means that both the rodent host populations and the flea populations need to be reduced at the same time and held below a certain level to prevent plague outbreaks. Serious progress in plague prevention depends on long-term studies and international collaboration between scientists from many disciplines, such as medical entomology, parasitology, molecular biology, mathematical modelling, and others.

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