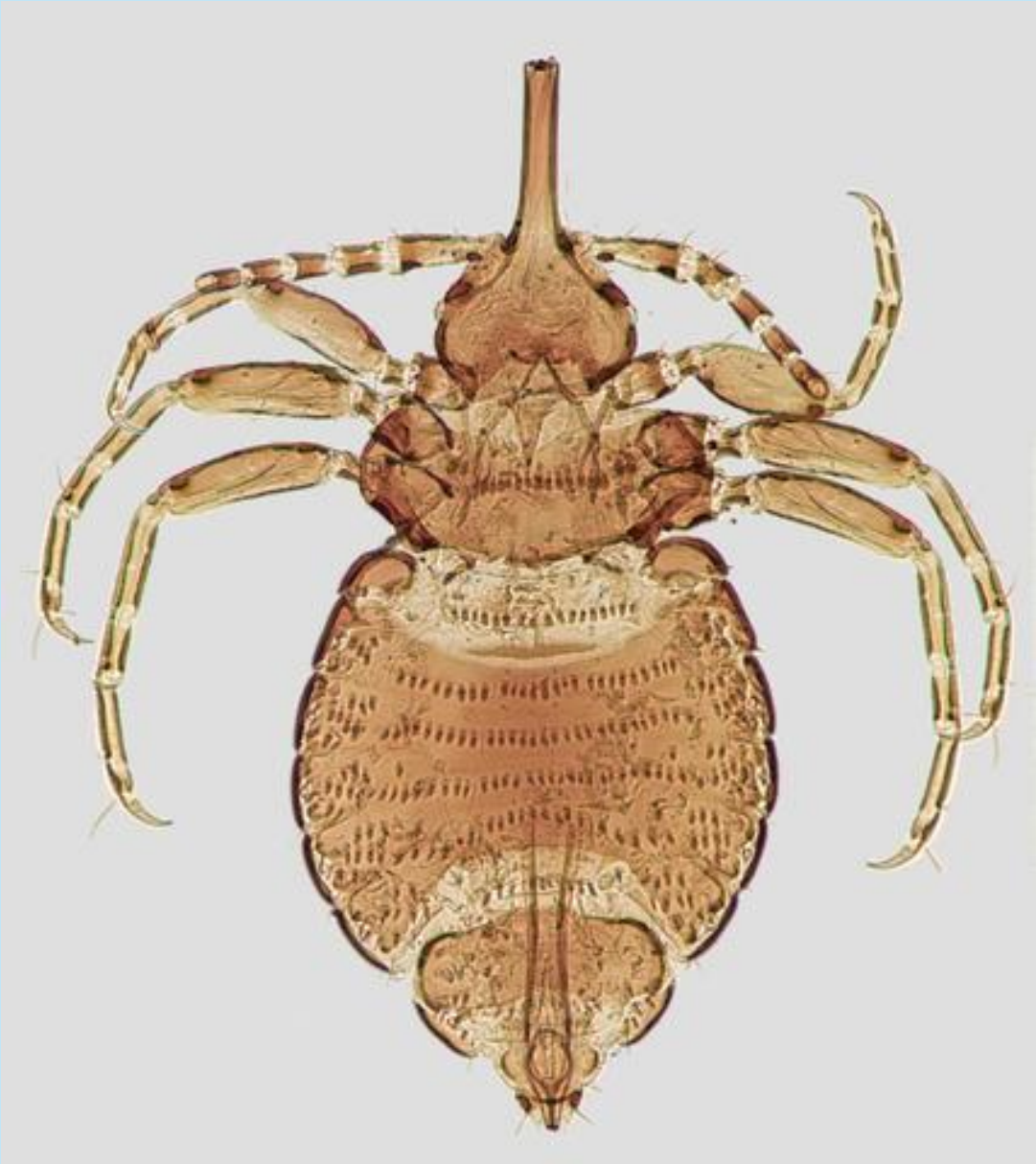
# FLEAS AND LICE: MEDICAL AND VETERINARY IMPORTANCE AND RECENT RESEARCH

Lance Durden

Georgia Southern University (Statesboro, GA)







*Haematomyzus elephantis* (Elephant Louse), Male

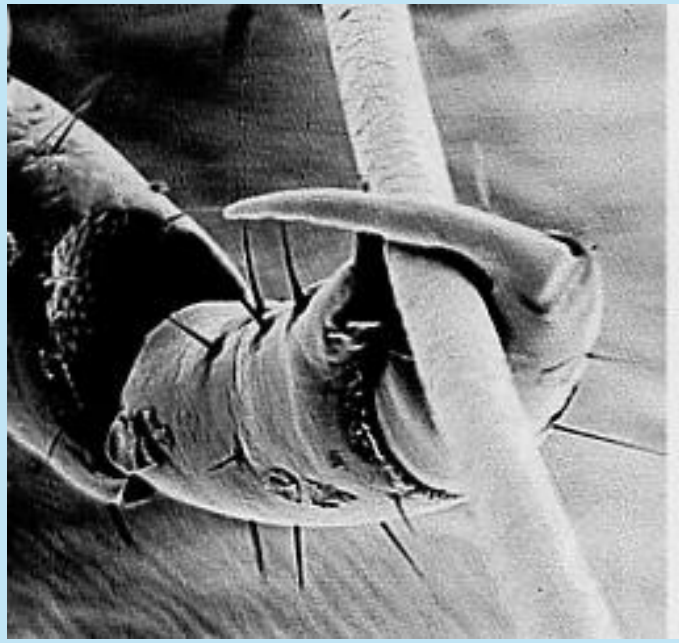
The elephant louse has a “trunk” and llama lice have long “necks!”



*Microthoracius mazzai* (Llama louse), Female



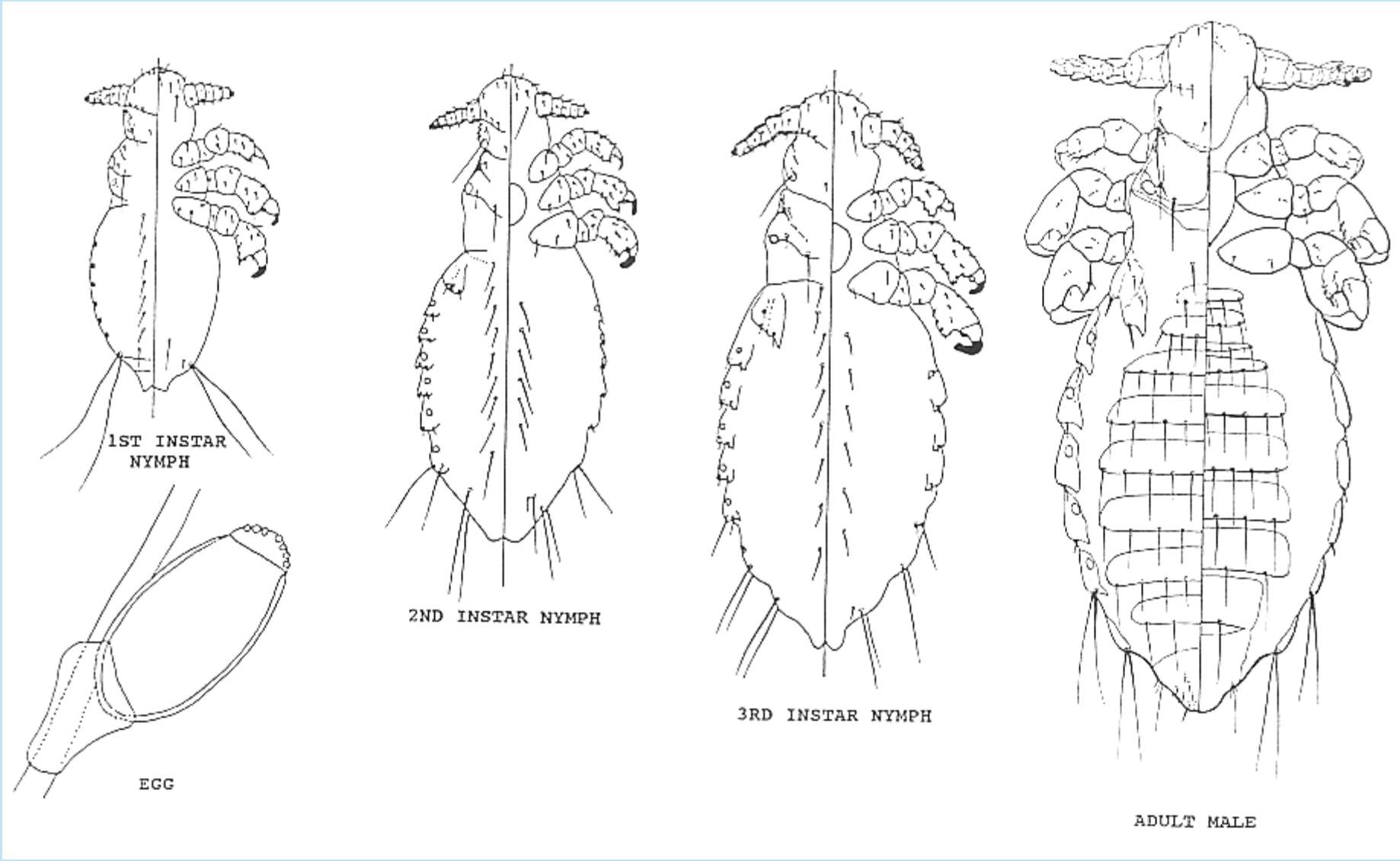
Human head/body louse, *Pediculus humanus*

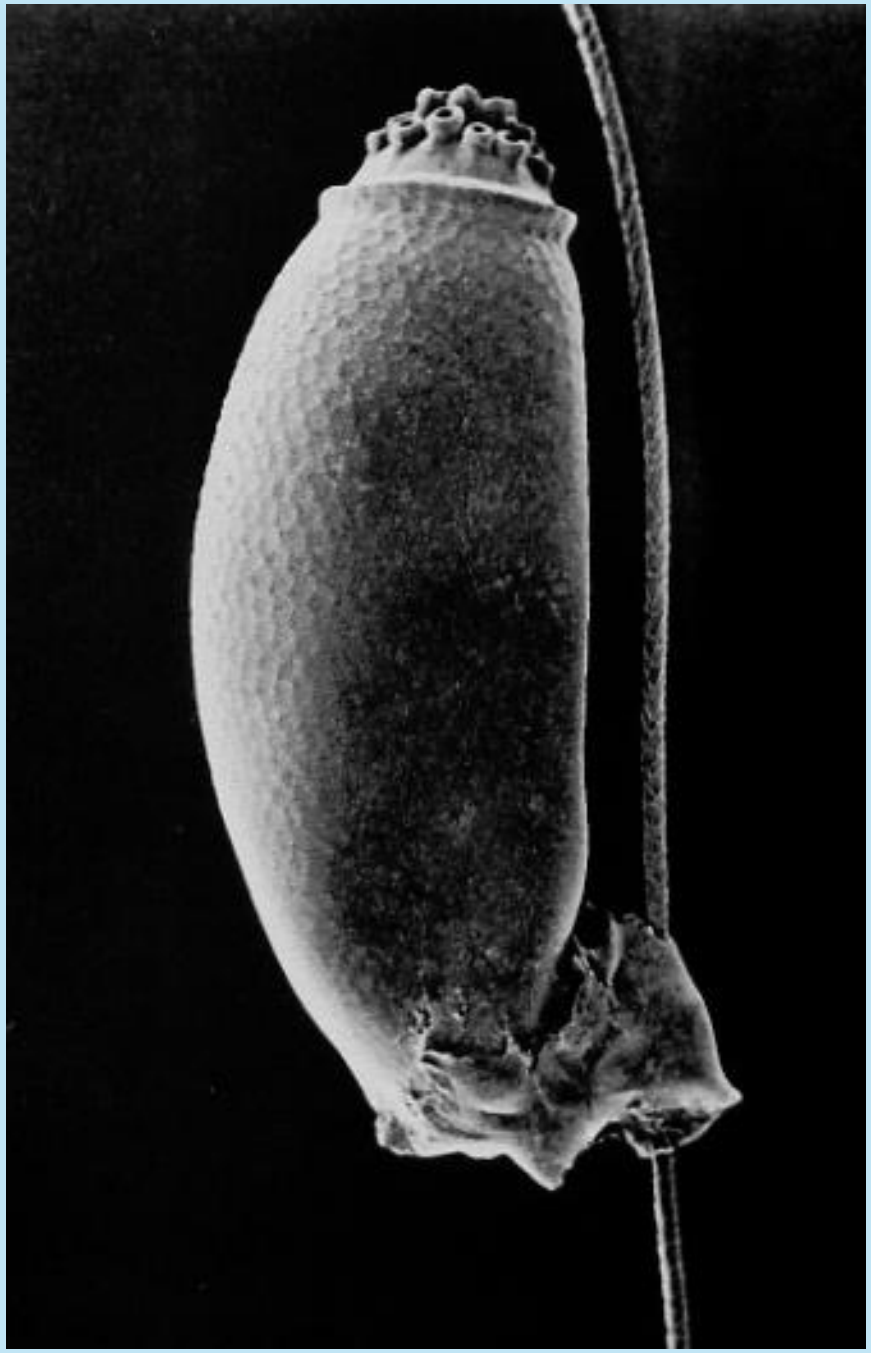


Sucking lice attach to host hairs with highly modified tibio-tarsal claws esp. on the hindleg. For host specific adult sucking lice, the gap within the hind tibio-tarsal claw positively correlates with host hair diameter.

~600 species of sucking lice have been documented worldwide.

Hemimetabolous developmental stages of a sucking louse (*Polyplax spinulosa* – spined rat louse) – all stages live on the host.





Egg (**nit**) of dog sucking louse, *Linognathus setosus*, cemented to host hair.

Note anterior cap (**operculum**) with tiny breathing holes (aeropyles). Hatching louse nymphs push off the operculum when they hatch.

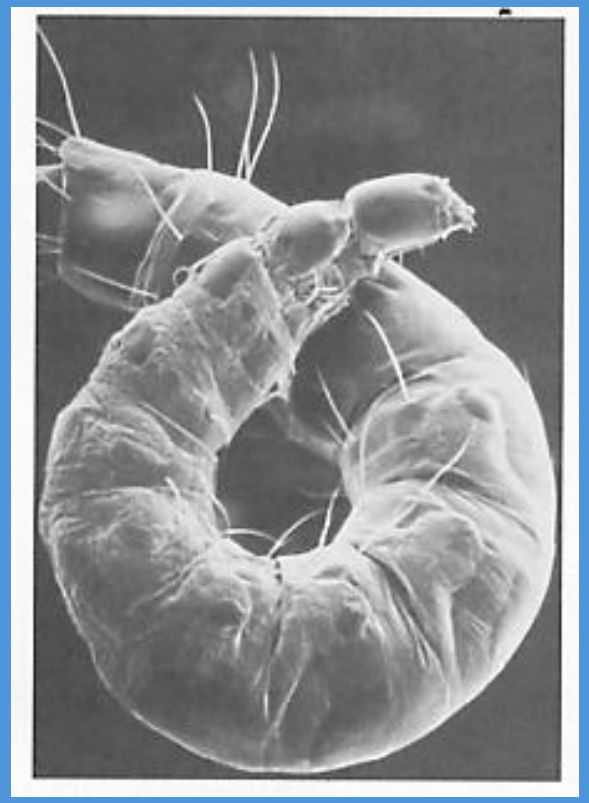
Egg cement entraps host DNA. Ancient human DNA has recently been extracted & sequenced from louse eggs on hairs of mummies.

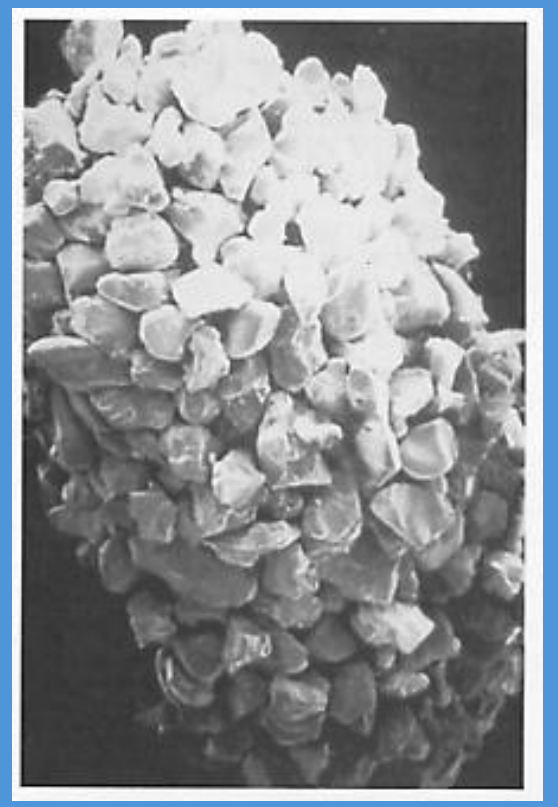



*Musserellus marshalli*
Mardon & Durden,
n. gen., n.sp. (male).

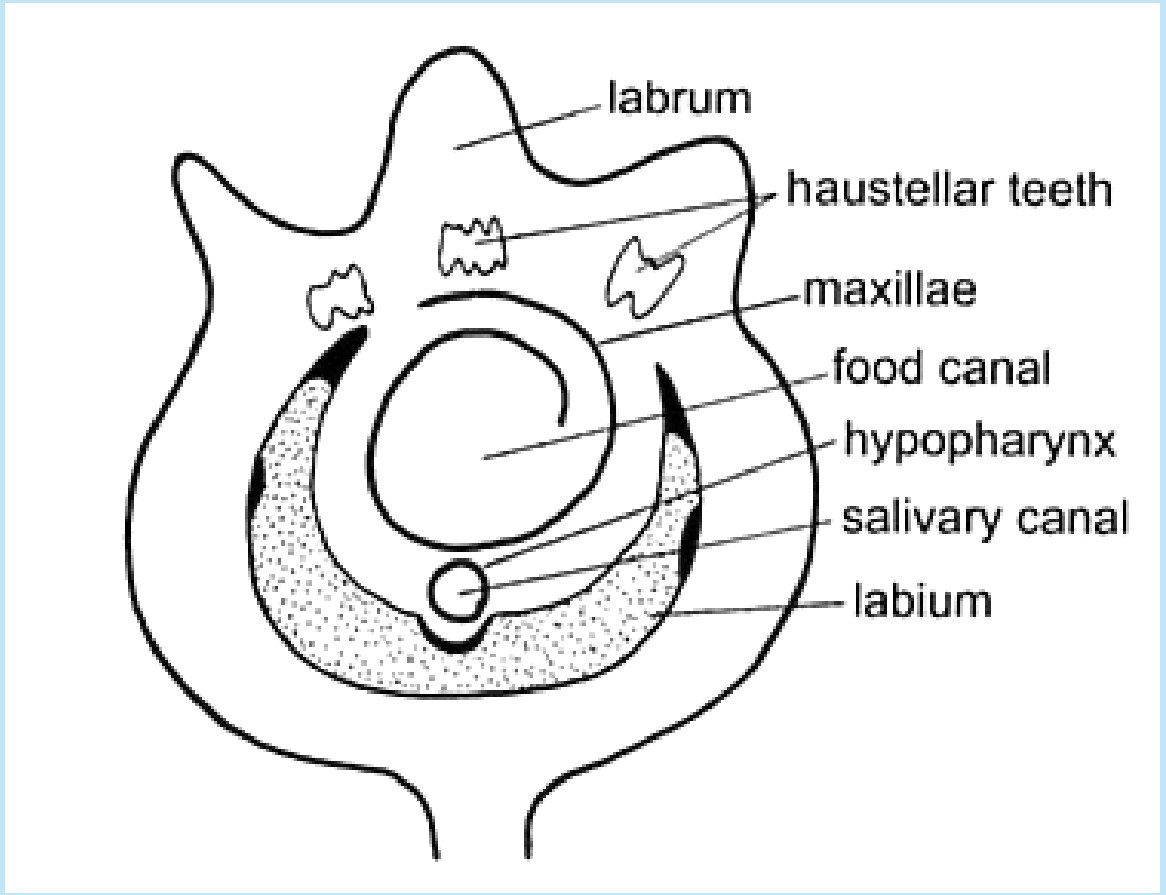
INDONESIA: Sulawesi
(Celebes).

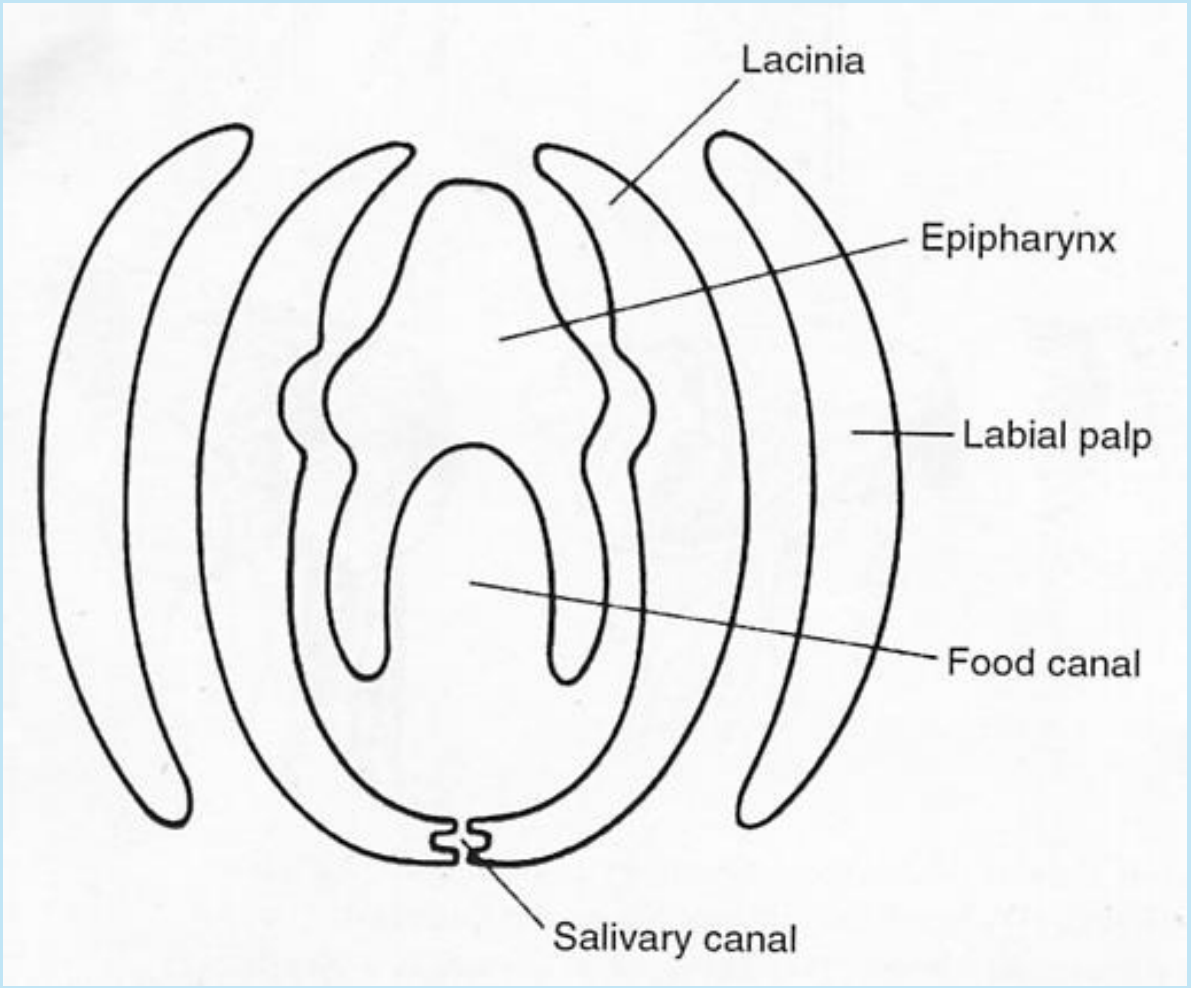
~3,000 species of fleas
have been documented
worldwide.



Holometabolous developmental stages of a flea (*Ctenocephalides felis* – cat flea), egg, larva, pupae and cocoon (covered with sticky debris) – all immature stages live off the host (with 2 known exceptions).




Cross section of sucking louse (left) and adult flea mouthparts showing different structures forming food (blood) canals and salivary canals.



# The Sucking Lice (Phthiraptera: Anoplura) of Georgia, USA: Hosts, Geographical Distributions, and Medical/Veterinary Importance[1]

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Department of Biology, Georgia Southern University, Statesboro, Georgia 30458, USA

J. Entomol. Sci. 49(3): 246-272 (July 2014)

**Abstract** Twenty-five species of sucking lice (Phthiraptera: Anoplura) are recorded from Georgia, USA. One of these species is currently recognized as 2 distinct subspecies, the body louse (*Pediculus humanus humanus* L.) and head louse (*Pediculus humanus capitis* De Geer) of humans. Gray squirrels, southern flying squirrels, humans, and domestic cattle are parasitized by relatively rich faunas of sucking lice in Georgia with 3 characteristic species/ subspecies recorded from each of these hosts within the state. Despite some previously published erroneous host-louse records, most species of sucking lice are host specific in Georgia. Sucking lice have been recorded from domestic hogs, cattle, equines, goats, and dogs in Georgia, and some of these lice can cause veterinary problems. The head louse is common in Georgia, especially in school children. The crab/pubic louse [*Pthirus pubis* (L.)] also appears to be widespread in the state. We report only one verified record of the body louse from Georgia, but we suspect this louse persists focally in the state. In nature, the body louse is a vector of at least 3 important pathogens: those that cause epidemic typhus, louse-borne relapsing fever, and trench fever. None of these diseases are currently known to be circulating in human populations in Georgia, but "urban" trench fever could be present in some homeless populations. Flying squirrels and their lice are known reservoirs and vectors, respectively, of an enzootic cycle of *Rickettsia prowazekii* da Rocha-Lima which can infect humans causing sporadic epidemic typhus. Taxonomically, we correct the description date for 2 anopluran species, *Polyplax serrata* (Burmesiter) and *Polyplax spinulosa* (Burmeister), from 1839 to 1838.

**Key Words** sucking lice, Anoplura, Phthiraptera, Georgia, hosts, geographical distribution, medical importance, veterinary importance

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doi: 10.1093/jme/tjx039
Advance Access Publication Date: 2 March 2017
Research article

Vector-Borne Diseases, Surveillance, Prevention

# Molecular Markers of Pesticide Resistance and Pathogens in Human Head Lice (Phthiraptera: Pediculidae) From Rural Georgia, USA

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Subject Editor: Kevin Macaluso

Received 27 August 2016; Editorial decision 16 January 2017

## Abstract

Although the head louse, *Pediculus humanus capitis* De Geer, and body louse, *Pediculus humanus humanus* L., both have a worldwide distribution, the occurrence of head louse pediculosis appears to be more prevalent in modern societies despite systematic use of various pediculicides. This study tested head lice collected in rural Georgia and body lice collected in Russia for the prevalence of a *kdr*-biomarker that is associated with permethrin resistance. This study also screened lice for the presence of DNA from *Bartonella quintana* and *Acinetobacter* species. The *kdr*-permethrin resistance biomarker for the T917I mutation was detected by RFLP and PCR in 99.9% of head lice tested from Georgia, whereas only 2.9% of body lice from Russia tested positive for this *kdr* biomarker. DNA of *B. quintana* was detected in 10.3% of head lice from Georgia, whereas 84.8% of body lice from Russia tested positive. *Acinetobacter* DNA was detected in 80.8% (95% CI, 68–89%) of head lice from Georgia and all body lice from Russia tested.



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Medical and Veterinary Entomology

ORIGINAL ARTICLE

# A severe head louse (*Pediculus humanus capitis*) infestation: Timeline, pathogen detection, *kdr*-gene screening and morphological anomalies of lice

# ТЯЖЕЛЫЙ СЛУЧАЙ ГОЛОВНОГО ПЕДИКУЛЕЗА (*Pediculus humanus capitis*): ИСТОРИЯ ЗАРАЖЕНИЯ, ДЕТЕКЦИЯ ПАТОГЕНОВ, СКРИННИГ KDR-ГЕНА, И МОРФОЛОГИЧЕСКИЕ АНОМАЛИИ ВШЕЙ

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**Associate Editor:** Daniel Martín-Vega

## Abstract

Lice are assuming an increasing importance in forensic investigations, given their capacity to provide information about an individual's care. Head louse pediculosis is a frequent condition in school-age children and can be properly controlled using topical treatments combined with good personal hygiene. Prolonged and chronic infestations may result in more serious outcomes including severe iron deficiency anaemia. We conducted entomological and laboratory investigations of a head louse infestation in a 12-year-old girl who experienced severe anaemia and subsequent death. Numerous lice were found postmortem on the head, face and neck of the patient, as well as on bedding and clothing. Analysis of nits on individual hairs determined that the louse infestation had been present for at least 166 days. The lice had some morphological traits characteristic of body lice: the third antennal segment in some specimens was distinctly longer than wide, and the apices of some paratergal plates did not extend into intersegmental membranes, while other morphological features were characteristic of head or body lice. All lice were heterozygous for the T917I *kdr* genotype, a marker of permethrin resistance. Nineteen (79.2%, 95%CI 59.5%–90.8%) louse DNA samples tested TaqMan positive for *Acinetobacter* (Moraxellales; Moraxellaceae) sp. Available information and laboratory findings are further discussed regarding their possible contribution to the negative outcome of this case. We stress the impact head louse pediculosis can have on children with limited parental attention, and how severe head louse infestation may serve as warning sign of neglect, and other high-risk situations.

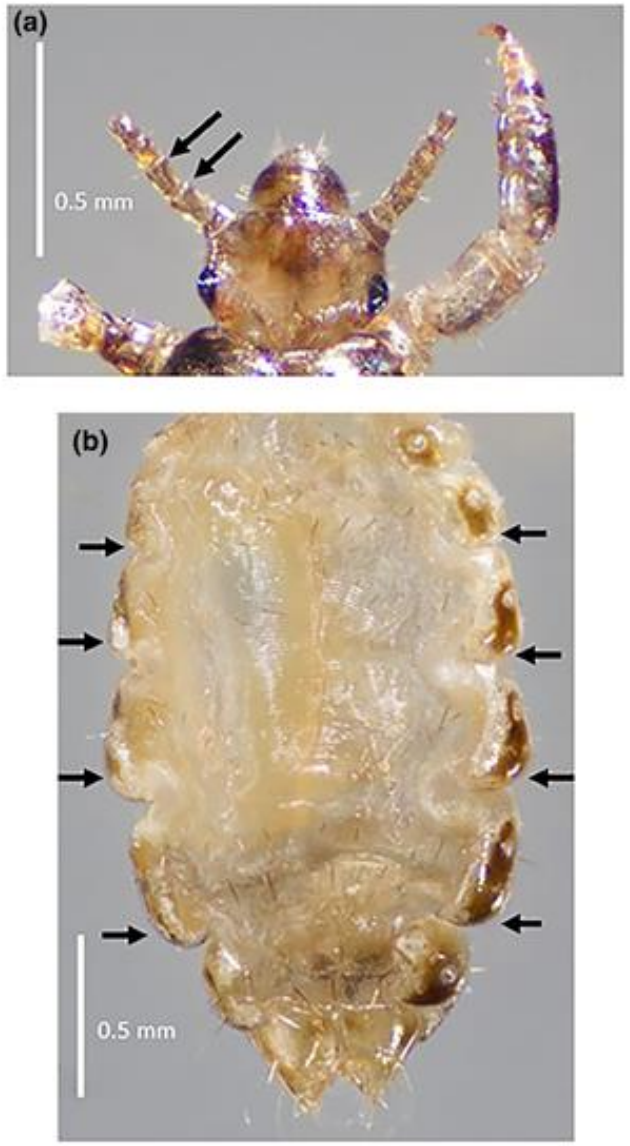



**FIGURE 1** Adult female head louse (*Pediculus humanus capitis*) collected from clothing (hooded sweatshirt) of the child. (a) Dorsal head showing third antennal segment (arrows at each end) longer than wide as typically seen in body lice (*Pediculus humanus humanus*). (b) Dorsal abdomen showing apices of most paratergal plates (arrows) not extending into intersegmental membranes as typically seen in body lice.

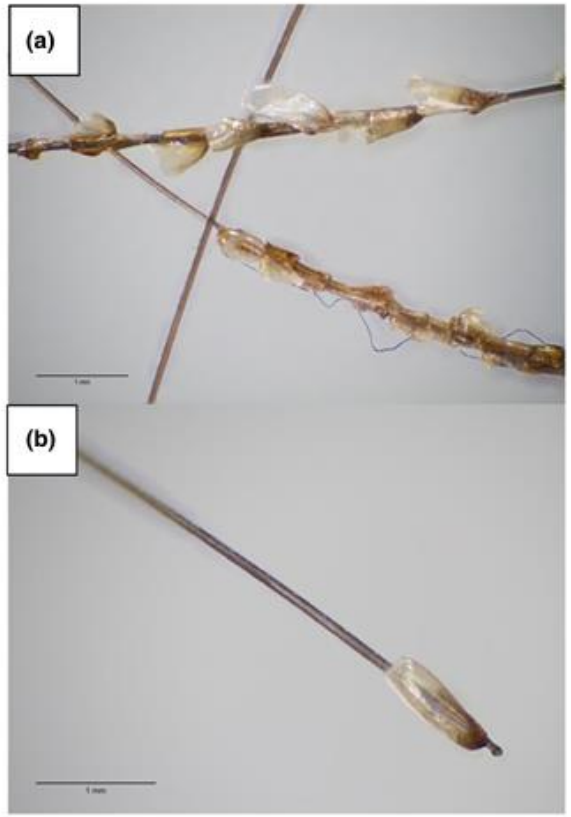



**FIGURE 2** Documentation of the severe head louse infestation. (a) A sample of the hatched nits attached to head hairs found on the clothing (hooded sweatshirt) of the child. (b) Single nit attached closely to the hair root.



*Pthirus pubis* (Human Crab/Pubic Louse), Male & Female, cleared & stained w. acid fuschin








**Human pubic/crab louse, *Pthirus pubis***

TOP: Adult females

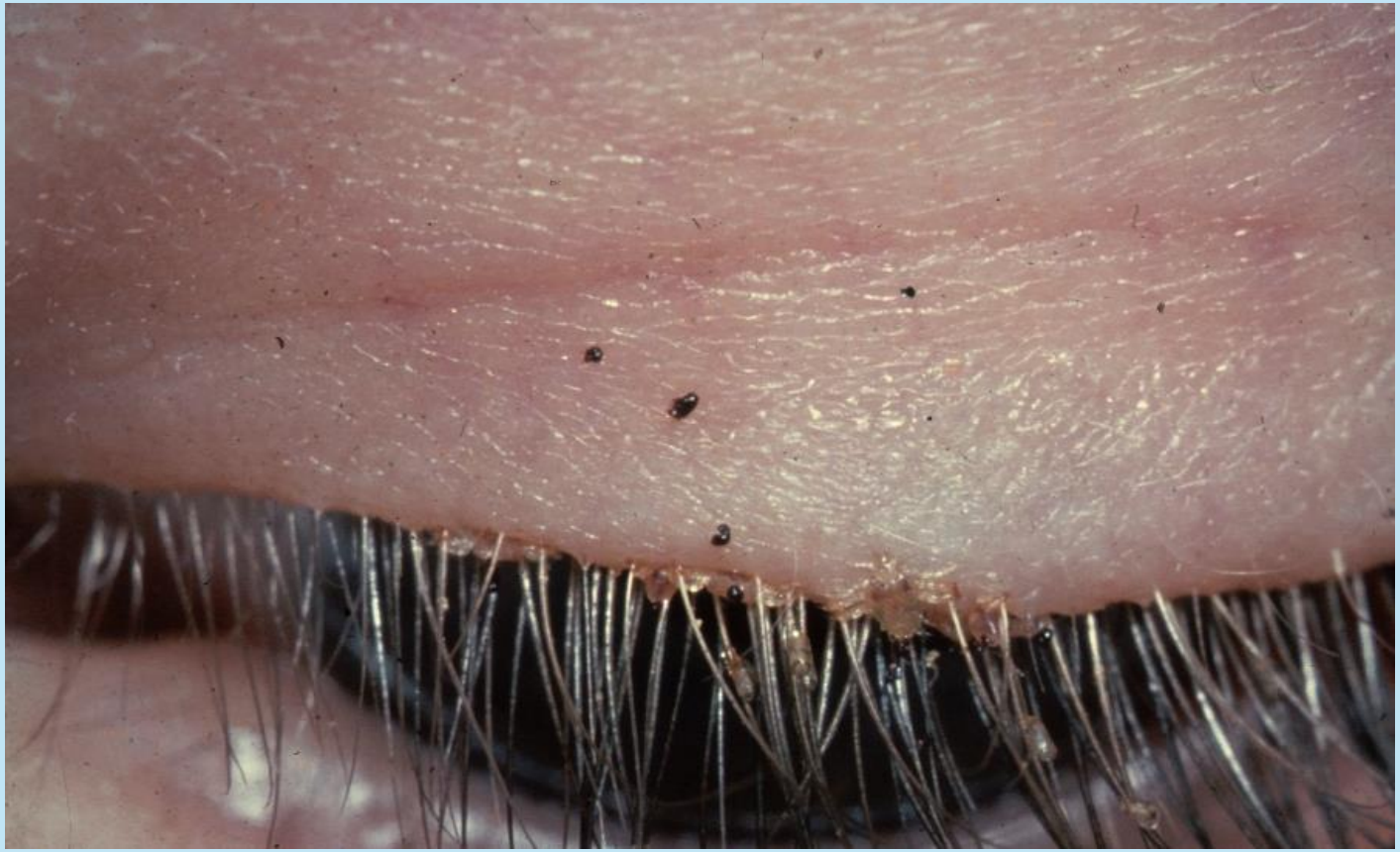
BOTTOM: Feeding lesions on skin.

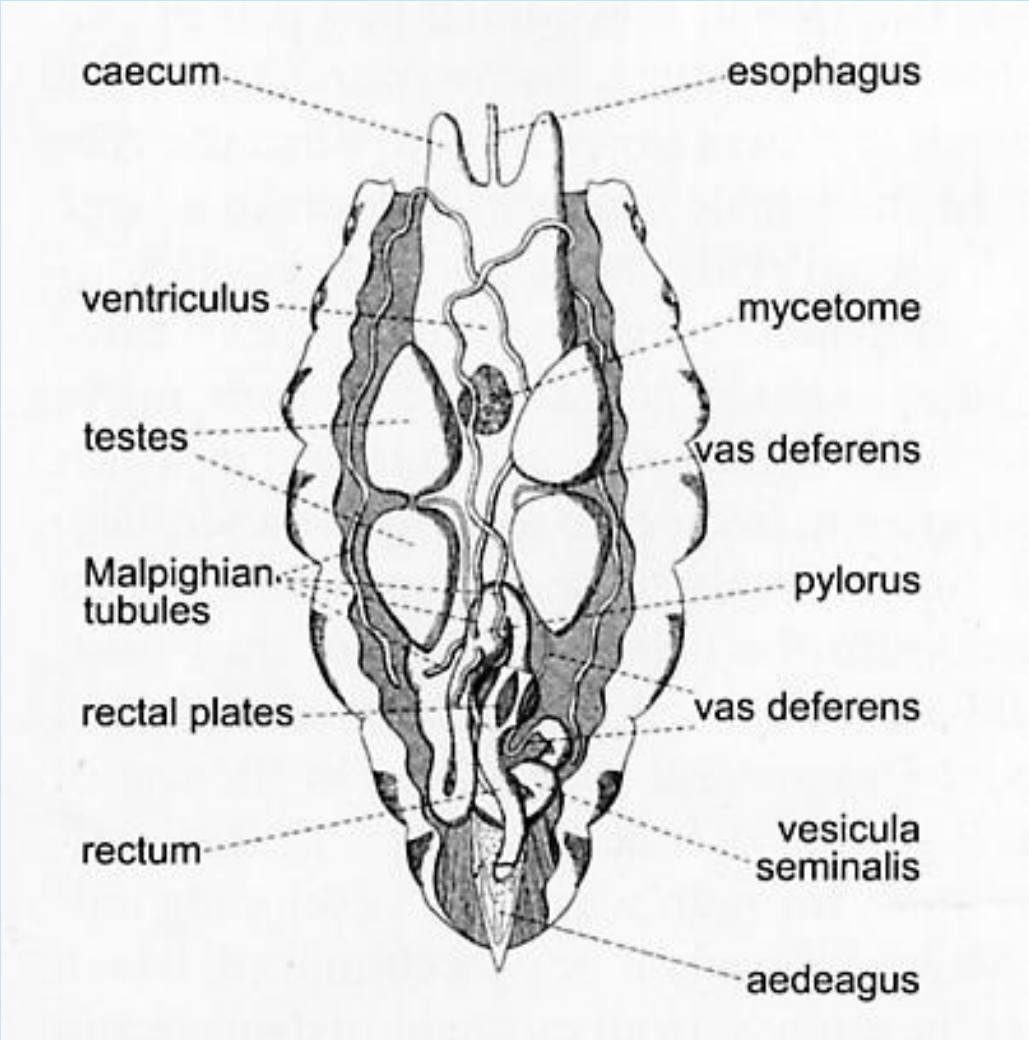
Note large tibiotarsal claws for gripping thicker (pubic) hairs.

Pubic lice can also infest other body sites that have stouter hairs (under arms, eyelashes & eyebrows of both sexes; beards, moustaches, chest hair, sometimes even back hair of males).



Crab lice & nits on eyelashes; feces on eyelids






**Internal abdominal anatomy of a male human body louse**

**(*Pediculus humanus humanus*)**



**FIG. 2.** Human head louse nymph, showing the white, circular mycetome in the abdomen where primary endosymbionts are housed. Photo credit: J. M. Allen.

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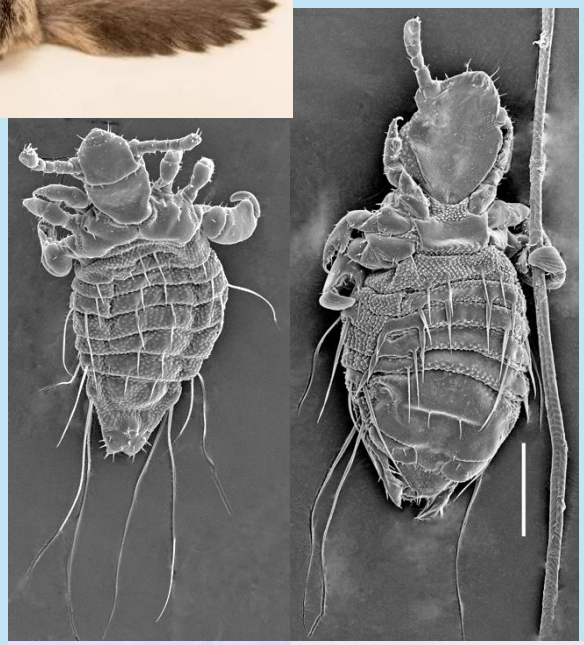
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# A new genus and new species of sucking louse (Phthiraptera: Anoplura: Enderleinellidae) from the particoloured flying squirrel (*Hylopetes alboniger*) in Laos, and an updated identification key to enderleinellid genera

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## Abstract

*Hylophthirus spinosus*, **new genus and new species** (Phthiraptera: Anoplura: Enderleinellidae), is described from specimens collected from the particoloured flying squirrel, *Hylopetes alboniger* in Khammouane Province, Laos (Lao People's Democratic Republic). Both sexes of the new louse are illustrated with stacked microphotographs, scanning electron micrographs and line drawings. An updated morphological identification key to the six genera (*Atopophthirus, Enderleinellus, Hylophthirus, Microphthirus, Phthirunculus* and *Werneckia*) now recognised within the family Enderleinellidae is presented. The new genus is unique within the Enderleinellidae in having massive spines (modified setae) on some abdominal sternites, partially bulbous 5th antennal segments, mesothoracic spiracles borne on protuberances and the morphology of the genitalia of both sexes. Tables showing all genera of sucking lice that include species parasitising sciurids (squirrels, chipmunks, susliks and marmots), and all known species of enderleinellids, with their known host associations and geographical distributions are included and briefly discussed in relation to the new genus and species.

**THE USA IS THE ONLY COUNTRY TO HAVE BOTH THE LARGEST AND SMALLEST SUCKING LOUSE IN THE WORLD!**




Collared peccary/Javalina (*Pecari tajacu*)





← *Microphthirus uncinatus*, female.

Flying Squirrels, *Glaucomys* spp.



*Pecaroecus javalii, M*ale

Table 6.3 Pathogens Transmitted by Lice

| Disease | Disease Agent | Vector(s) | Host(s) | Geographic Distribution |
|---|---|---|---|---|
| VIRAL: | | | | |
| Swinepox | Pox virus | *Haematopinus suis* | Hogs | Widespread |
| BACTERIAL: | | | | |
| Epidemic typhus | *Rickettsia prowazekii* | *Pediculus h. humanus* | Humans | Global (focal) |
| Louse-borne relapsing fever | *Borrelia recurrentis* | *Pediculus h. humanus* | Humans | Global (focal) |
| Trench fever | *Bartonella quintana* | *Pediculus h. humanus* | Humans | Global |
| Tularemia | *Francisella tularensis* | Rodent & lagomorph lice | Rodents, rabbits | Global |
| Murine Mycoplasma Infection | *Mycoplasma muris* | *Polyplax spinulosa* | Domestic rats | Global |
| Murine Mycoplasma Infection | *Mycoplasma coccoides* | *Polyplax serrata* | Domestic mice | Global |
| FUNGAL: | | | | |
| Bovine dermatomycosis (ringworm) | *Trichophyton verrucosum* | Cattle lice | Cattle | Global |
| HELMINTHIC: | | | | |
| Seal heartworm | *Dipetalonema spirocauda* | *Echinophthirius horridus* | Harbor seal | Northern Hemisphere |
| Avian filariasis | *Eulimdana* spp. | Bird chewing lice | Charadriiform birds | Widespread |
| Avian filariasis | *Pelecitus fulicaeatrae* | *Pseudomenopon pilosum* | Aquatic birds | Holarctic region |
| Avian filariasis | *Sarconema eurycerca* | *Trinoton anserinum* | Geese, swans | Holarctic region |
| Double-pored tapeworm* | *Dipylidium caninum* | *Trichodectes canis* | Dogs, humans | Global |

*Lice are intermediate hosts, not vectors, of this tapeworm.

**EPIDEMIC TYPHUS (= Louse-Borne Typhus, Jail Fever, etc.)**

•Transmitted to humans by the body louse (*Pediculus humanus humanus*). Body lice are currently rare in N. America (virtually eradicated). Main demographic group that MAY have body lice are homeless people in inner cities.

•Caused by infection w. rickettsial bacterium, *Rickettsia prowazekii.*

•Bacterium is transmitted in feces of infected lice – lice defecate while feeding – we later scratch bites & bacteria enter through skin.

•Disease is currently rare in developed countries but has shaped human history. Sometimes it re-emerges (esp. in Africa) during wars, famine, etc.

•More of Napoleon's troops were killed by epidemic typhus than by Russian soldiers during 1812 invasion of Russia; ~10 million humans died of Epidemic Typhus during WWII.



SIGN ON NAPLES ROAD WARNS SOLDIERS AGAINST LICE

# Human Body Lice (*Pediculus humanus humanus*)



Feeding on a human (note feces being released during feeding)



Eggs (nits) attached to clothing (often along seams)

## SYMPTOMS OF EPIDEMIC TYPHUS

•Abrupt onset of fever (10-14 d after exposure).

•Headache & muscle aches; malaise; cough.

•A blotchy (rosy) rash starts on the abdomen & spreads to the chest – sometimes over entire body.

•Prostration & delirium develop.

•Coma & low blood pressure occur in severe cases.

•Case fatality rate: 10-20% in untreated cases – but 100% has been recorded.

•Treatment is w. doxycycline.

•A vaccine exists but not v. effective.



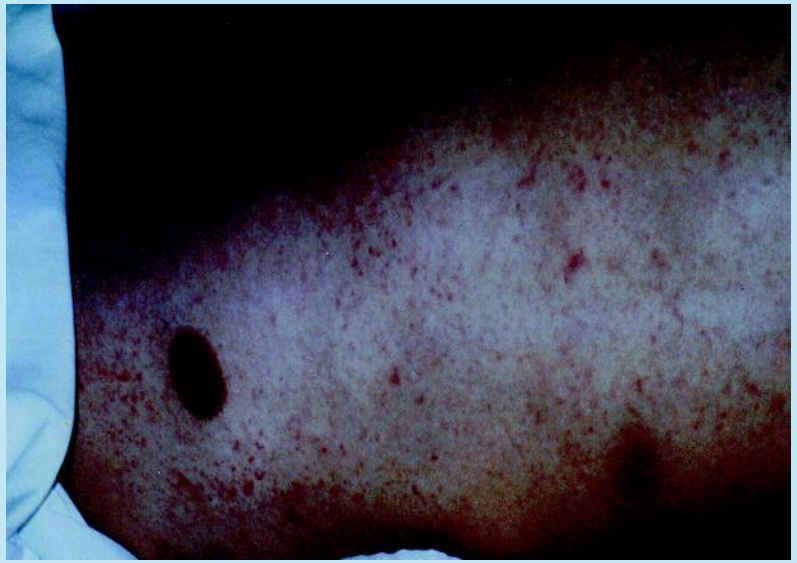
Abdominal blotchy rash of Epidemic Typhus in a male, Burundi, 1996 (before major outbreak)



Rose-colored trunk lesions of Epidemic Typhus (Day 4 of disease onset)



Rash of Epidemic Typhus on torso, neck & arms



Diffuse petechial rash of Epidemic Typhus (Day 7 of disease onset)

•1816-1819: ~ 700,000 cases in Ireland – coupled with the potato famine, this led to many deaths & to widespread emigration to USA.

•U.S. immigrants from European countries sometimes had “relapses” of the disease up to 30 years later – called “Brill Zinsser disease” (for Nathan Brill & Hans Zinsser) or “Recrudescent Typhus.”

•This led to outbreaks in USA esp. where body lice were common.

•Last U.S. outbreak - Philadelphia (1877).

•1960s: U.S. flying squirrels shown to be inapparent reservoir hosts - humans can be infected from them.

•Squirrel lice harbor the bacterium but do not bite humans

• Aerosol transmission of bacteria from louse feces suggested.



Hans Zinsser

# Sporadic Epidemic Typhus

- Causative agent: *Rickettsia prowazekii* (minor sequence differences from classic epidemic typhus strains).
- Reservoir hosts: flying squirrels - N. America - only known non-human vertebrate reservoirs.
- Sporadic human cases in USA – AR, CA, GA, IN, MA, MD, NC, NY, OH. PN, TN, VA, WV - no deaths.
- 10-20 human cases in U.S. typically recorded each year by CDC.
- Effective antibiotic treatment w. doxycycline.





Southern flying squirrel,

*Glaucomys volans,*

Reservoir of Sporadic Epidemic Typhus rickettsiae in N. America



# Trench Fever

- Caused by infection with the bacterium *Bartonella quintana* (formerly, *Rochalimaea quintana*).
- Transmitted by human body lice via feces – pathogen is scratched into skin at bite site.
- 1st noted during trench warfare in WWI – 200,000 cases in British troops alone.
- Re-emerged during WWII under similar conditions.
- Body lice & some humans are the only reservoirs – some people have inapparent infections.
- Typically causes high fever, incapacitation, prostration, etc. – rarely death (cfr is usually 2-3%).
- Recently re-emerged in inner-city homeless populations.

## URBAN TRENCH FEVER

- From 1945-1990, *B. quintana* infection in humans was rare.
- Since 1990, most patients have been homeless in inner cities.
- Many are chronic alcoholics and/or IV drug users; some are HIV positive.
- Louse-borne infections have been recorded in several cities: Seattle, Baltimore, New York City, San Francisco (USA), Marseille (France), Tokyo (Japan), Moscow (Russia).
- Urban Trench Fever is a re-emerging form of Trench Fever.

# URBAN TRENCH FEVER - TYPICAL SYMPTOMS

## BARTONELLA ENDOCARDITIS

Infection & inflammation of heart valves caused by *Bartonella* spp.

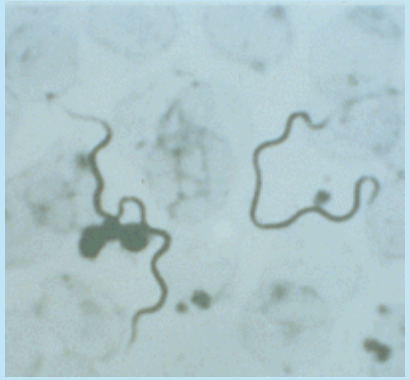
## BACILLARY ANGIOMATOSIS

Reddened vasoproliferative skin lesions caused by microcolonies of *Bartonella* spp.





# Louse-Borne (=Epidemic) Relapsing Fever



- Caused by infection with the spirochete bacterium, *Borrelia recurrentis*.
- Transmitted by human body lice – by crushing infected lice on skin - pathogen resides in louse hemocoel – cannot be transmitted orally or fecally.
- Causes high fever w. up to 10 relapses.
- Cfr ~10-30% depending on the outbreak.
- Currently absent from N. America.
- Still present in Ethiopia, parts of Russia, China, Andes, NW Africa, etc.
- Historically ($16^{th}$ – $18^{th}$ Centuries), entire villages were wiped out in Europe (e.g., England) when this disease swept through.

ANNALS OF CARNEGIE MUSEUM

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# THE FLEA (SIPHONAPTERA) FAUNA OF GEORGIA, U.S.A: HOSTS, DISTRIBUTION AND MEDICAL-VETERINARY IMPORTANCE

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## ABSTRACT

Host and distribution data are provided for the 26 species of fleas recorded from Georgia, U.S.A.: *Cediopsylla inaequalis*, *C. simplex* (rabbit flea), *Ctenocephalides canis* (dog flea), *C. felis* (cat flea), *Echidnophaga gallinacea* (sticktight flea), *Pulex irritans* (human flea), *P. simulans, Xenopsylla cheopis* (Oriental rat flea), *Polygenis gwyni, Conorhinopsylla stanfordi, Ctenophthalmus pseudagyrtes, Doratopsylla blarinae, Epitedia cavernicola, E. wenmanni, Nearctopsylla georgiana, Stenoponia americana, Ceratophyllus celsus, Nosopsyllus fasciatus* (northern rat flea), *Orchopeas howardi* (squirrel flea), *O. leucopus, O. pennsylvanicus, Leptopsylla segnis* (European mouse flea), *Odontopsyllus multispinosus, Peromyscopsylla hesperomys, P. scotti* and *Sternopsylla distincta texana.* Three of these species, *P. gwyni, N. georgiana* and *O. howardi*, were described from Georgia specimens. While some of these flea species appear to be widely distributed throughout Georgia, *C. inaequalis* represents an introduction on hosts introduced for hunting from western North America, *D. blarinae, E. cavernicola, N. georgiana, C. celsus* and *P. hesperomys* were recorded only from Piedmont or mountainous regions in northern Georgia, and *P. gwyni* was mainly recorded in the Coastal Plain of southern Georgia. *Nearctopsylla georgiana* is known from only a single specimen and has never been recorded outside of northern Georgia. Fleas associated with domestic rats (*Rattus norvegicus* and *R. rattus*) were abundant in Georgia, especially coastal and southern Georgia during the 1930s–1950s but currently appear to be uncommon in the state. There were concerted control efforts against *Rattus* spp. and their fleas during that time period because of their reservoir and vector status, respectively, for *Rickettsia typhi*, the causative agent of murine (endemic) typhus. Human cases of murine typhus in Georgia have almost disappeared in recent decades. Other flea-borne diseases in Georgia include cat flea rickettsiosis caused by *Rickettsia felis,* bartonellosis (including cat scratch disease caused by *Bartonella henselae*), and sylvatic epidemic typhus caused by certain strains of *Rickettsia prowazekii.* Further, cat and dog fleas are intermediate hosts of the double-pored tapeworm, *Dipylidium caninum*, which typically infects dogs but can also infect cats and humans if infected fleas are inadvertently ingested. Human and pet-biting fleas such as the cat flea can also cause flea-bite dermatitis in dogs, cats and humans. Poultry fleas such as *E. gallinacea* currently appear to be uncommon on domesticated birds in Georgia but this flea sometimes infests chickens, dogs and some other mammals in fairly large numbers.

KEY WORDS: checklists, flea-borne diseases, host-parasite associations, flea distribution

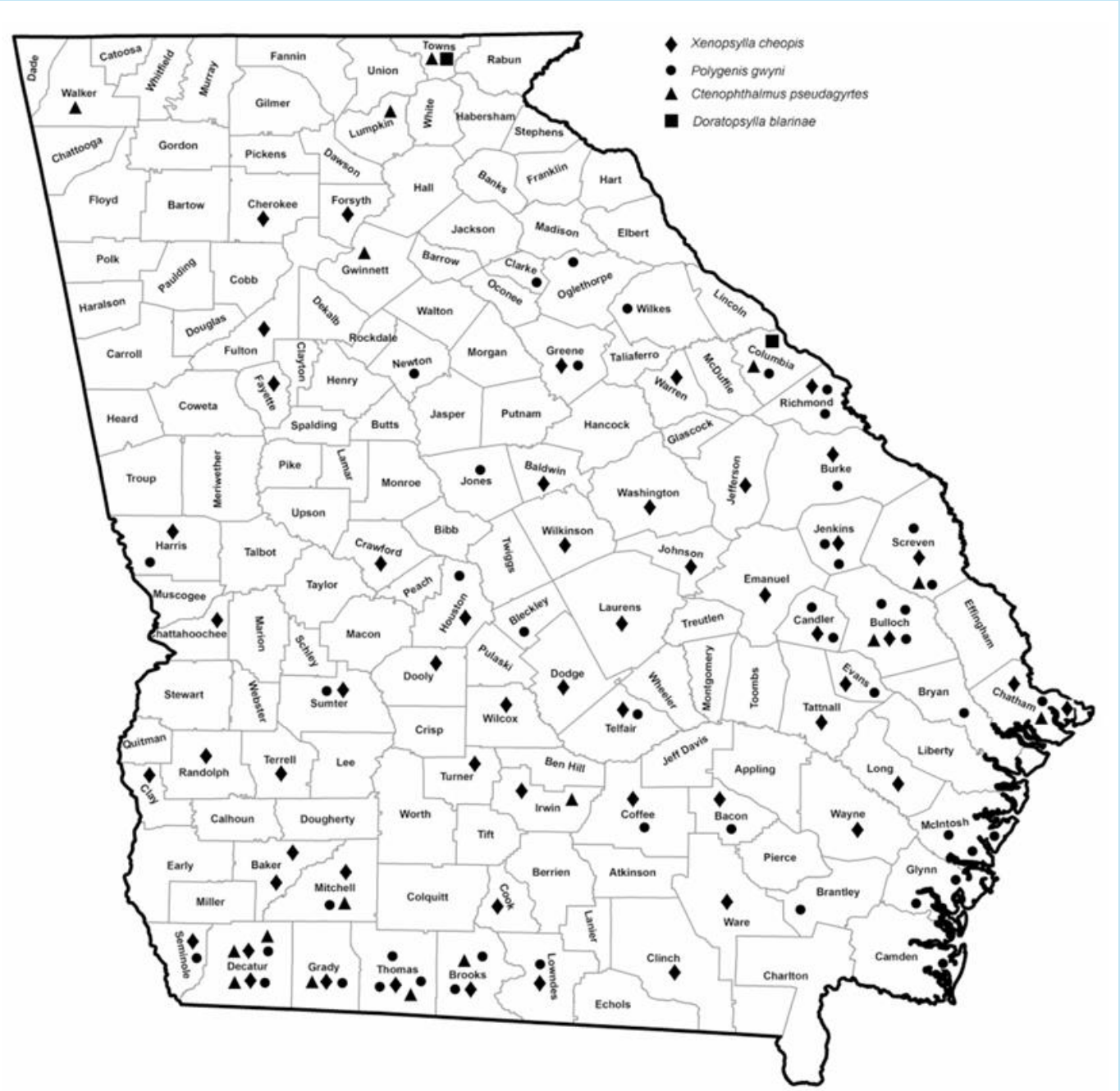


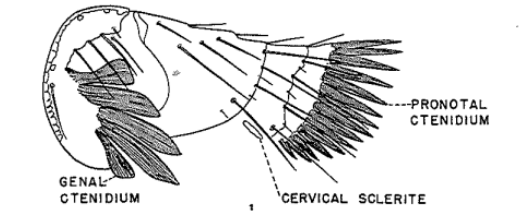

Fig. 3.—Recorded distributions of fleas in Georgia, U.S.A.: *Xenopsylla cheopis* (Pulicidae), *Polygenis gwyni* (Rhopalopsyllidae), *Ctenophthalmus pseudagyrtes* (Ctenophthalmidae), and *Doratopsylla blarinae* (Ctenophthalmidae).

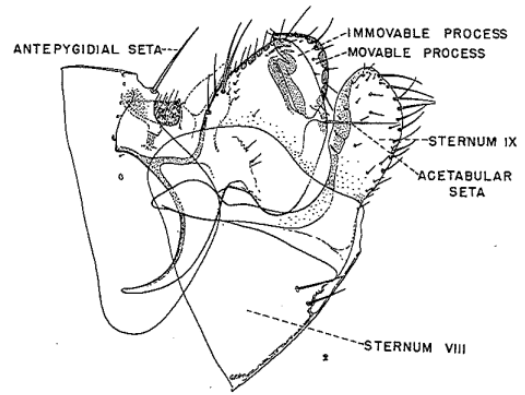


*Xenopsylla cheopis* (Oriental rat flea), Male




Fig. 4.—Recorded distributions of Ctenophthalmidae in Georgia, U.S.A.: *Conorhinopsylla stanfordi, Nearctopsylla georgiana, Stenoponia americana, Epitedia cavernicola,* and *Epitedia wenmanni*.




*Nearctopsylla georgiana*, new species: fig. 1, lateral aspect of head and pronotum; fig. 2, terminal abdominal structures. Fig. 2 drawn by G. P. Holland.

*Nearctopsylla georgiana* Pratt & Harrison, 1954, Male, Georgia: Brasstown Bald ex *Blarina brevicauda*.

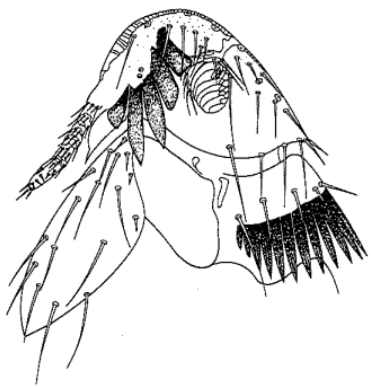


FIGURE 1. Head and thorax of *Nearctopsylla pfitzeri* sp. n.

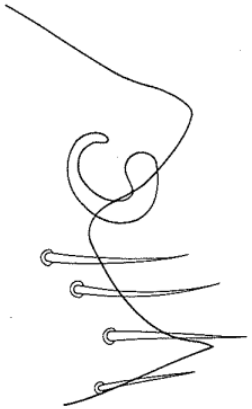


FIGURE 2. Sternite VII and spermatheca of *Nearctopsylla pfitzeri* sp. n.

*Nearctopsylla pfitzeri* Benton, 1981, Female, Tennessee: Roan Mountain ex Blarina brevicauda.





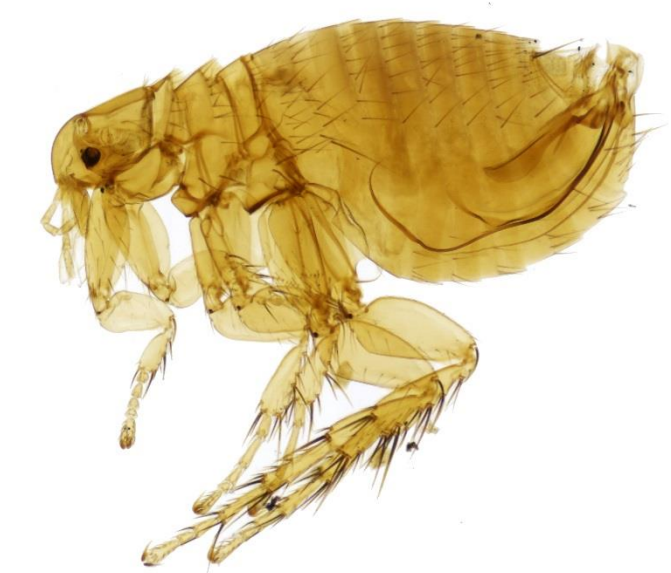
Sticktight flea, *Echidnophaga gallinacea* (female)

# Murine Typhus (= Flea-borne typhus)

**Causative agent:** *Rickettsia typhi*.

**Vectors:** Fleas, mainly the Oriental rat flea (*Xenopsylla cheopis*), also the cat flea (*Ctenocephalides felis*). Both flea species readily feed on humans.

**Transmission:** Posterior station – in feces of infected feeding fleas – can also rub into eyes or inhale from flea feces.




Oriental rat flea (male)



Cat flea (female on left, and male)

**Reservoir hosts:** Peridomestic rats (*Rattus rattus* and *Rattus norvegicus*) and (in N. America), Virginia opossums (*Didelphis virginiana*) – do not get sick from infection. Cats?

**Distribution:** Worldwide.

Introduced to USA probably in 1920's in infected rats and fleas at port cities (rats & fleas on ships from other countries)

Savannah, GA had the highest incidence of murine typhus in humans in the entire country in the 1930s and 1940s (1000s per year).

Also was common in other parts of GA (Atlanta, Albany, etc.) & the southern U.S. wherever peridomestic rats were common.

Government sponsored widespread control of rats with rodenticides (warfarin, etc.) & fleas with insecticides (mainly DDT) occurred starting in the 1940s.

Rat & flea control, combined with administration of antibiotics (starting in the 1940s) to infected people, made peridomestic rats, fleas, & murine typhus much less common in the USA.

# Reservoir hosts for murine typhus



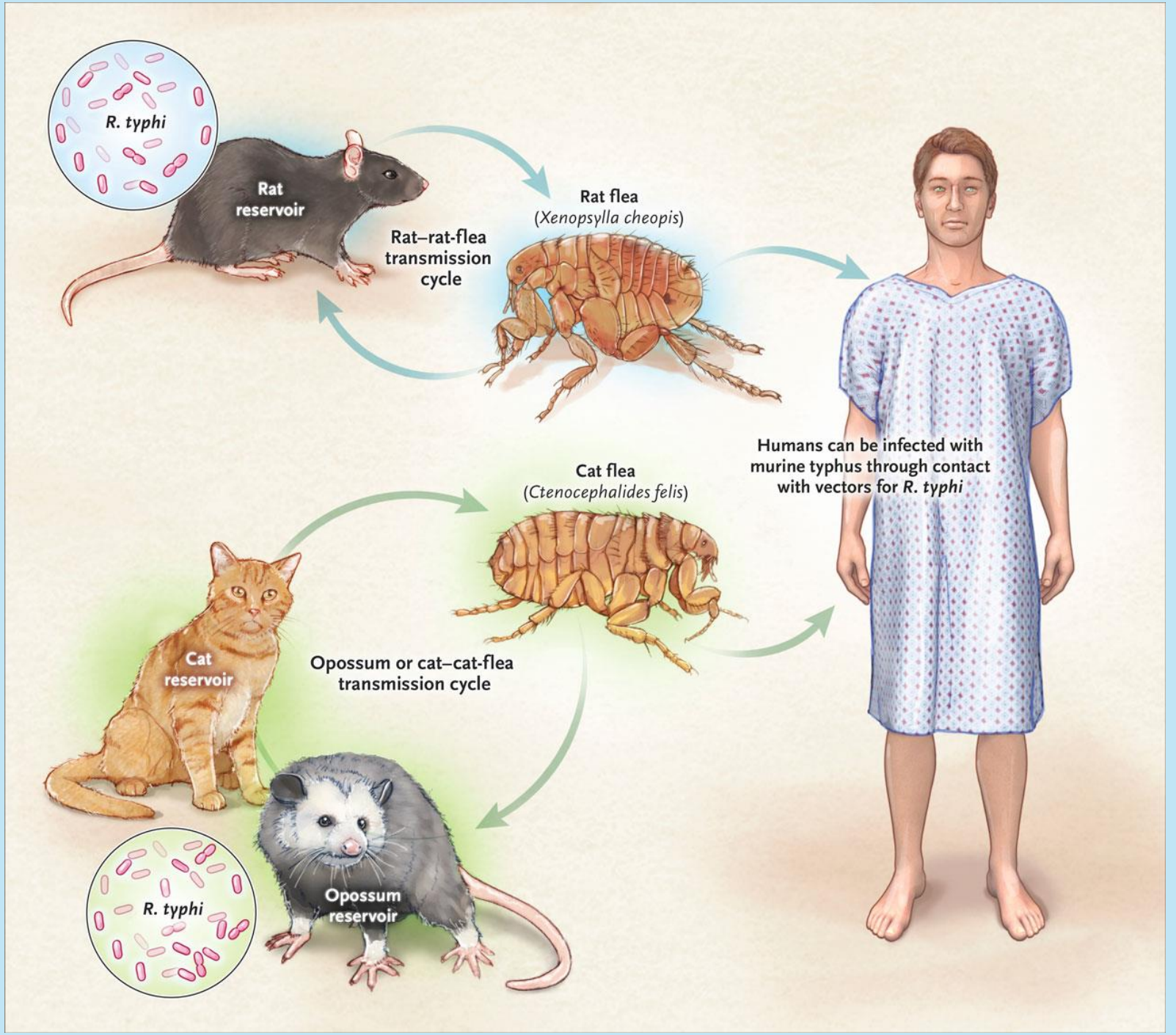
*Rattus rattus* (black/roof rat)



*Rattus norvegicus* (brown/Norway rat)



*Didelphis virginiana* (Virginia opossum)


R. typhi
Rat reservoir
Rat–rat-flea transmission cycle
Rat flea
(Xenopsylla cheopis)
Humans can be infected with murine typhus through contact with vectors for R. typhi
Cat flea
(Ctenocephalides felis)
Cat reservoir
Opossum or cat–cat-flea transmission cycle
R. typhi
Opossum reservoir

# Re-emergence of murine typhus in the USA

- Murine typhus was never eradicated from the USA.
- Hotspots persist (in suburban areas of Texas, California & Hawaii).
- *R. typhi* is also sometimes recorded in rodents or their ectoparasites in other parts of the U.S. (e.g., South Carolina).
- Does *R. typhi* still circulate between rats and fleas in GA (e.g., international ports in Savannah, Brunswick)? Are humans still sometimes infected?
- *R. typhi* now also infects Virginia opossums in N. America (a host switch).
- Cat fleas readily feed on Virginia opossums and humans.
- More pet & feral cats has led to more cat fleas, which can easily switch to opossums.
- The opossum-cat flea-human connection accounts for most current human cases of murine typhus in the U.S.
- Cases of human infections have been increasing in recent years esp. in Texas (100s of cases each year).
- NO VACCINE

# Murine Typhus in Humans

- An **Eschar** (reddish lesion w. blackish necrotic center) usually forms on the skin where transmission occurred from an infected arthropod.
- Mild cases: rash, fever, malaise; some patients can not work or function normally for 2-3 months.
- Severe cases: rash, high fever, organ damage/failure (lungs, kidneys, liver, heart or brain), prostration, delirium, coma, sometimes death (cfr for untreated patients is ~ 5%).
- Treatment: Antibiotics (doxycycline or tetracycline).
- Avoidance: control fleas on pets, feral cats, etc.





**Eschar and rash of murine typhus**



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# DETECTION OF *RICKETTSIA* AND *BARTONELLA* IN FLEAS AND TICKS COLLECTED FROM PETS AT VETERINARY CLINICS IN GEORGIA, UNITED STATES

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**KEY WORDS**

Dogs
Cats
Ticks
Fleas
*Rickettsia*
*Bartonella*
Cat-scratch disease
Owner survey

**ABSTRACT**

Many human infections are transmitted through contact with household pets. The purpose of this cross-sectional study was to determine the occurrence of ticks and fleas on pets (dogs and cats) in local veterinary clinics in Statesboro, Georgia. We screened ectoparasites for *Rickettsia* and *Bartonella* and assessed owner knowledge and practices related to tick- and flea-borne diseases. Ectoparasites were collected and identified using standard taxonomic keys, and their genomic DNA was extracted. Three TaqMan assays were used to test ectoparasites for flea-borne *Rickettsia* DNA. Nested PCR targeting riboflavin synthase encoding gene (*rib*C) was used to detect *Bartonella* species DNA. Restriction fragment length polymorphism analysis and sequencing were used to identify the microorganisms detected. Upon providing written consent, owners completed a self-administered questionnaire to provide information concerning their knowledge and practices about vector-borne diseases. Data from 27 pets were collected from 2 veterinary clinics during September to December 2014. A total of 58 ectoparasites including fleas (n = 51) and ticks (n = 7) were collected from 19 cats and dogs. The cat flea, *Ctenocephalides felis* (n = 44), was the predominant flea species followed by *Pulex* sp. (n = 7). All ticks were *Ixodes scapularis*. Using PCR, RFLP, and sequencing, it was determined that the majority of cat fleas contained DNA of known human pathogens, including *Rickettsia asembonensis* (72.5%), *Rickettsia felis* (5.9%), *Bartonella henselae* (2%), and *Bartonella quintana* (7.8%). DNA of *B. quintana* was also detected in 2 *Pulex* sp. fleas and 2 ticks. Two animals had ectoparasites co-infected with *Rickettsia* and *Bartonella*. Most owners (95.7%) knew that fleas can transmit animal disease agents, but they were less aware that fleas can spread diseases to humans, and only 12.5% of owners knew about cat scratch disease. Our data indicate that there is a risk of flea- and tick-borne zoonotic infections in households owning cats and dogs. Educational materials, vector-control preventive measures, and appropriate personal attitudes and practices are needed to ensure public health safety and wholesome interactions with pets.



*Ctenocephalides felis* (Cat Flea - Male) – vector of *Bartonella henselae* & *Rickettsia felis*



*Pulex irritans* ("Human" flea), male

**Table III.** Ectoparasites and zoonotic pathogens detected in them from cats and dogs in the 2 veterinary clinics in Statesboro, Georgia.*

| Collection Site | No | Host | Age | Gender | Number of ectoparasites collected (sex) | Ectoparasite Species | *Rickettsia* | | | | *rib*C-*Bartonella* sp. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | *bio*B-RF | *omp*B-RT | *omp*B-RA | RFLP | |
| Clinic 1 | 1 | Cat | 4 yr | Male | 3 (2♀, 1♂) | *Ctenocephalides felis* | 3 | 0 | 3 | 2 (A) | 0 |
| | 2 | Cat | 5 mo | Male | 2 (2♀) | *C. felis* | 1 | 1† | 1 | 1 (A) | 2 (Q, H) |
| | 3 | Cat | 3 mo | Male | 5 (3♀, 2♂) | *C. felis* | 5 | 0 | 3 | 5 (3A, 2F) | 0 |
| | 4 | Cat | 9 mo | Male | 3 (3♀) | *Ixodes scapularis* | 0 | 0 | 0 | 0 | 1 (Q) |
| | 5 | Dog | 4 mo | Female | 5 (3♀, 2♂) | *C. felis* | 5 | 0 | 5 | 5 (A) | 0 |
| | 6 | Dog | 8 mo | Female | 4 (2♀, 2♂) | *C. felis* | 4 | 0 | 4 | 4 (A) | 0 |
| | 7 | Dog | 8 yr | Female | 1 (1♀) | *C. felis* | 1 | 1† | 1 | 1 (A) | 1 (Q) |
| | 8 | Dog | 4 yr | Female | 4 (3♀, 1♂) | *C. felis* | 3 | 3† | 3 | 3 (A) | 0 |
| | 9 | Dog | 6 mo | Female | 2 (2♀) | *I. scapularis* | 0 | 0 | 0 | 0 | 0 |
| | 10 | Dog | NR | Female | 1 (1♀) | *I. scapularis* | 0 | 0 | 0 | 0 | 0 |
| | 11 | Dog | 1.5 mo | Male | 3 (2♀, 1♂) | *C. felis* | 3 | 0 | 3 | 3 (A) | 0 |
| | 12 | Dog | 4 yr | Male | 2 (1♀, 1♂) | *C. felis* | 2 | 0 | 2 | 2 (A) | 0 |
| | 13 | Dog | 1 yr 6 mo | Male | 1 (1♀) | *C. felis* | 1 | 0 | 1 | 1 (A) | 0 |
| | 14 | Dog | 5 yr | Male | 1 (1♀) | *C. felis* | 0 | 0 | 0 | 0 | 0 |
| | 15 | Dog | NR | Male | 1 (ND) | *C. felis* | 1 | 1† | 0 | 1 (F) | 0 |
| | 16 | Dog | 5 mo | Male | 1 (1♀) | *Pulex* sp. | 0 | 0 | 0 | 0 | 0 |
| Clinic 2 | 17 | Dog | NR | Female | 7 (6♀, 1♂) | *Pulex* sp | 0 | 0 | 0 | 0 | 2 (Q) |
| | 18 | UNK | NR | Unknown | 11 (9♀, 2♂) | *C. felis* | 11 | 0 | 11 | 7 (A)‡ | 0 |
| | 19 | UNK | NR | Unknown | 1 (1♀) | *I. scapularis* | 0 | 0 | 0 | 0 | 1 (Q) |
| TOTAL | | | | | 58 | | 40 | 6 | 37 | 35 | 7 |

* ♀ = female; ♂ = male; (A) *Rickettsia asembonensis* RFLP profile; (F) *Rickettsia felis* RFLP profile; (H) DNA of *Bartonella henselae* identified by Sanger sequencing; NR: information was not recorded; (Q) DNA of *B. quintana* identified by Sanger sequencing; UNK: information is not available.
† Ct value detected is much higher compared to corresponding Ct values for *bio*B and *omp*B-RA TaqMan (≤40).
‡ Adequate amount of amplicon was produced only for samples testing positive with low Ct values by TaqMan assay.

The “chigoe,” “jigger flea” or “sand flea,” *Tunga penetrans*.

A tiny tropical flea w. free-living males & subdermally embedded females.

Females swell to size of pea in tissues (esp. toes & hands of humans; feet, snouts, teats, genitalia of pigs; feet & snouts of dogs.

Lesions are prone to secondary bacterial infection & may form abscesses, septicemia or gangrene – amputations may be necessary.

Re-emerging in rural S. America & sub-Saharan Africa. Also increasing in travelers.

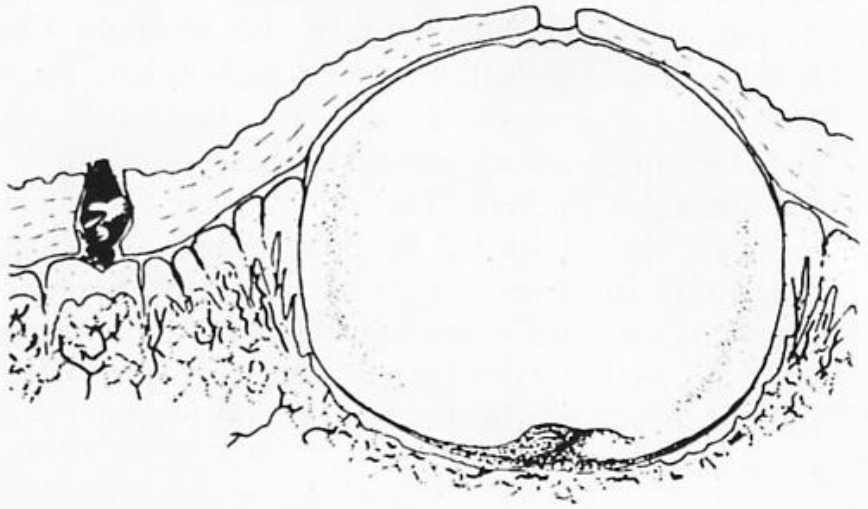
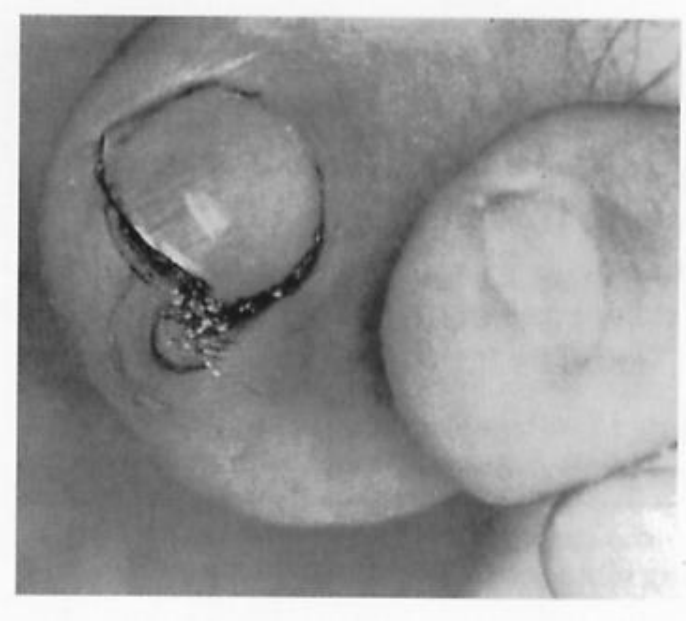


FIGURE 7.12 Chigoe (*Tunga penetrans*), adult females embedded in host skin; abdominal segments starting to swell in specimen at left; greatly enlarged, gravid female at right. (From Harwood and James, 1979.)







*Tunga penetrans*, neosomic, embedded females, different stages of engorgement.

# Tungiasis lesions in feet and hand caused by embedded female chigoes, *Tunga penetrans*





Male (left) & engorging female chigoes



Surgical removal of chigoe



**Figure 9.13** Tungiasis; several female *Tunga penetrans* embedded in a dog's snout. (Chiebao et al., 2005)

# PLAGUE (Bubonic Plague, Black Death, etc.)

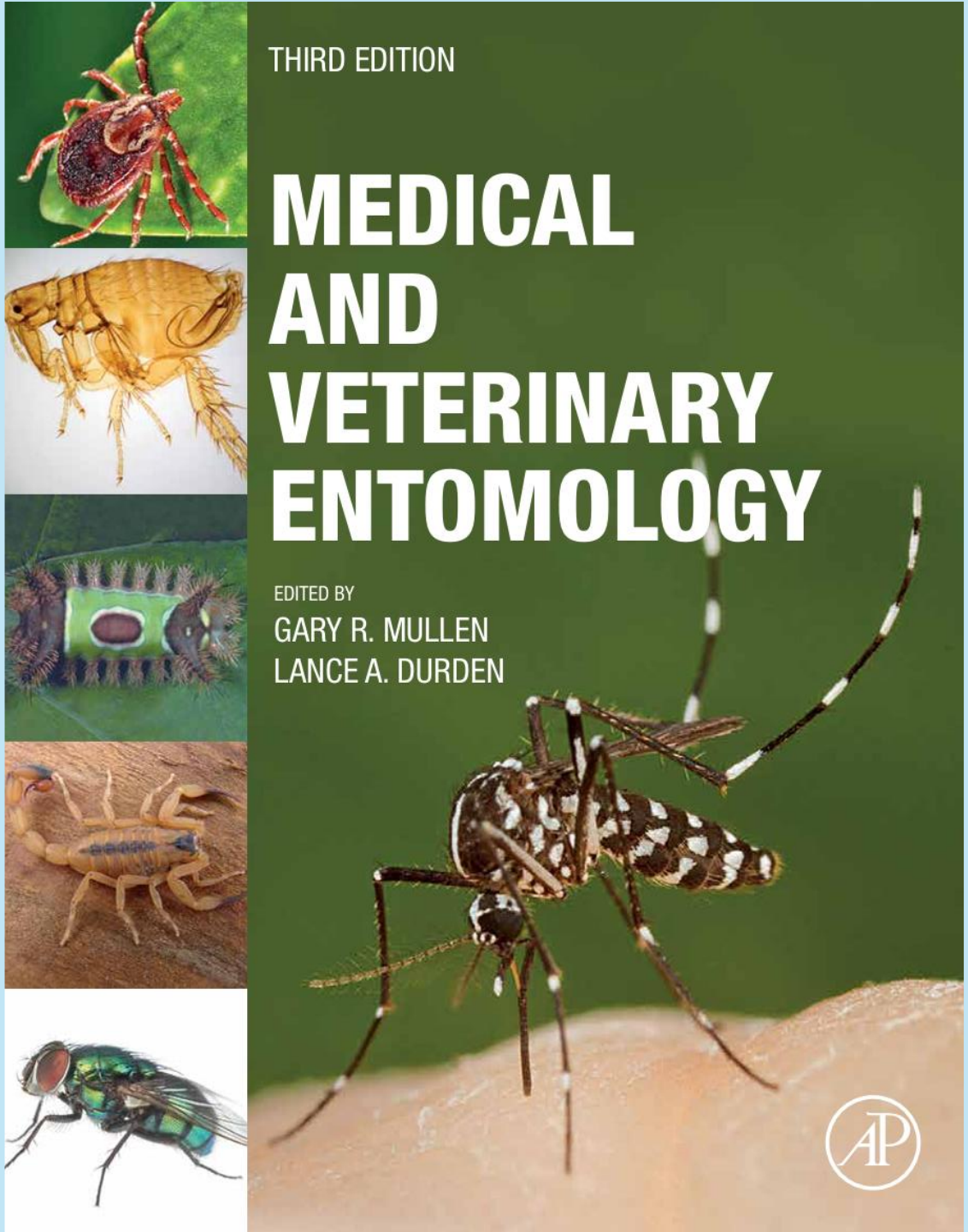




- Causative agent: *Yersinia pestis* (Gram-negative bacterium).
- 3 recorded Pandemics during human history:
  - Justinian's Plague: (541-767); ~40 million human deaths.
  - Black death: (1347-1666): >25 million human deaths.
  - Modern Plague: (1855-1948): >25 million human deaths (12 million in India).
- Fleas are known vectors, esp. *Xenopsylla cheopis* (Oriental rat flea) in urban areas, but several other flea spp. in rural regions.
- Several current plague hotspots worldwide; most of the ~2,000 current cases/yr. are in Dem. Rep. of Congo & Madagascar.
- Flea-borne plague was introduced into San Francisco (from rats on ships docking from Hong Kong) in 1898 and spread – now present in all western states U.S. where native rodent fleas (e.g., *Oropsylla montana*) are vectors - <40 human cases typically reported by CDC each year – many cases are fatal.
- Multidrug resistant plague currently circulates in Madagascar.
- Human body louse is an efficient exptl. vector of *Y. pestis*.
- Some researchers now believe body lice (with fleas) were important vectors during plague pandemics.

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