

Insecta, Ectognatha

1. Hemimetabolous insects

Palaeoptera (Ephemeroptera, Odonata)

Neoptera:

Polyneoptera (e.g. Plecoptera, Blattodea, Isoptera, Dermaptera)

Paraneoptera (e.g. Pthiraptera, Heteroptera, "Homoptera")

Pthiraptera: (Psocoptera = pisivky),
sucking louse (Anoplura = vši),
elephant louse (Rhynchophthirina = všiváci),
chewing louse (Ischnocera, Amblycera = všenky)



2. Holometabolous insects

Oligoneoptera = Holometabola (e.g. Neuroptera, Mecoptera, Lepidoptera, Diptera, Aphaniptera, Coleoptera)

Anoplura (sucking louse)

Monophyletic, wingless

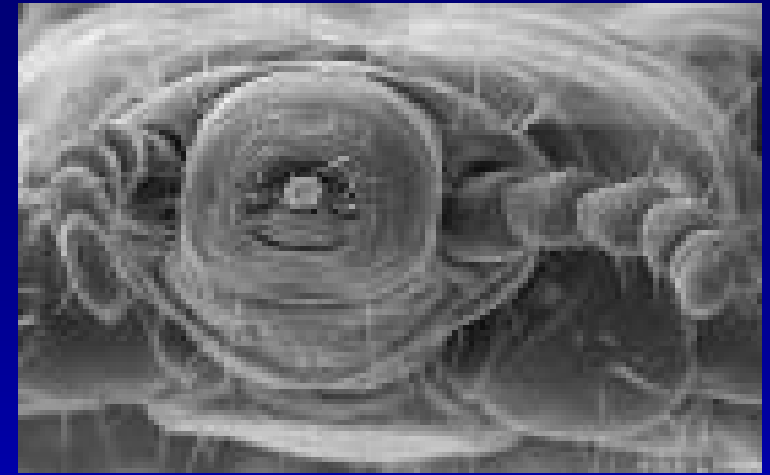
3 nymphal stages, all parasitic

Only in mammals, about 500 species

Females glue eggs (nits = *hnidy*) to hairs

Permanent parasites, high host specificity.

Legs with grasping organs: single claw and opposing "thumb"



Examples of animal louse

Haematopinus:

lice on ungulates,
largest lice (up to 7 mm),
H. suis (hog louse), rare in domestic
pigs, frequent in wildbore.

H. eurysternus

(shortnosed cattle louse)

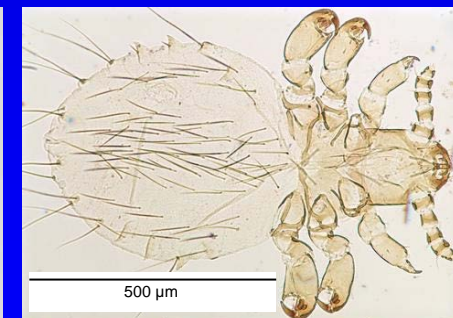
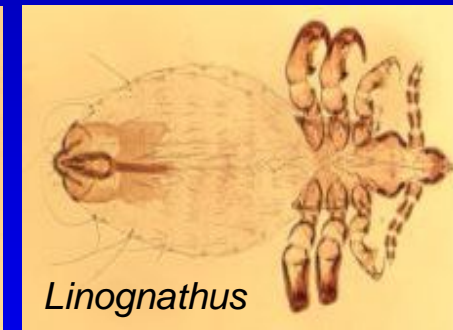
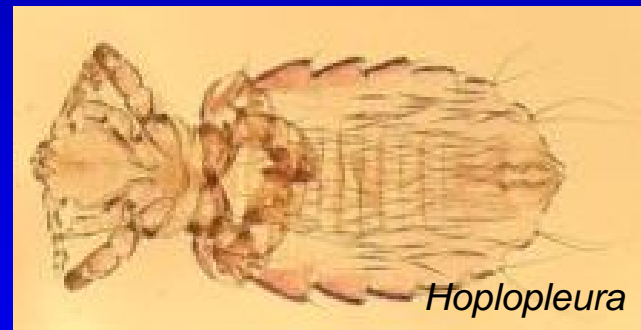
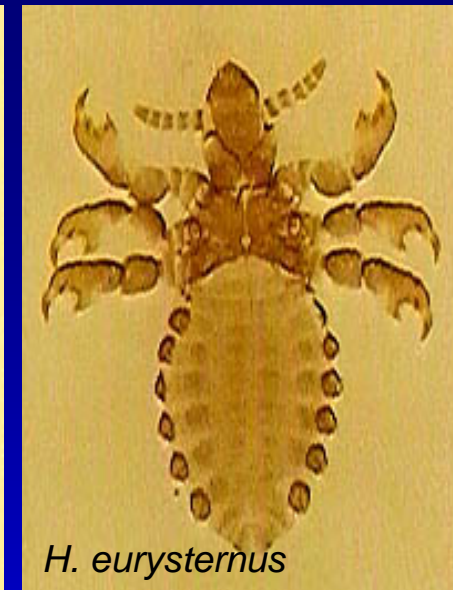
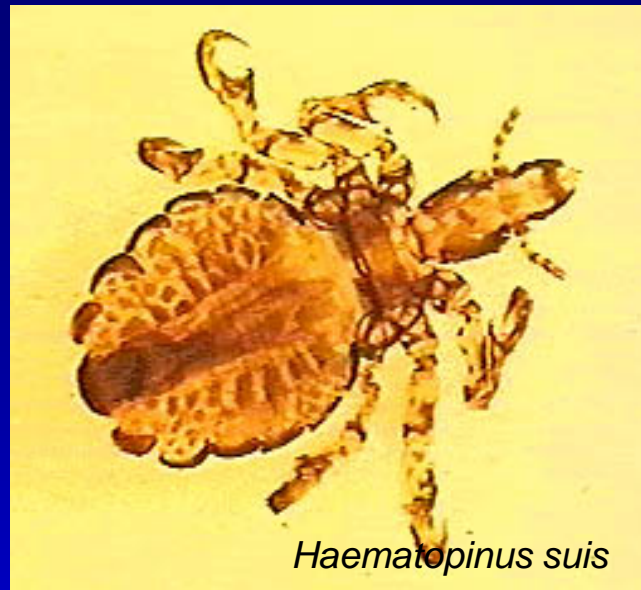
veterinary important in cattle farms.

Hoplopleura, Polyplax and others:

Frequently in rodents

High host specificity.

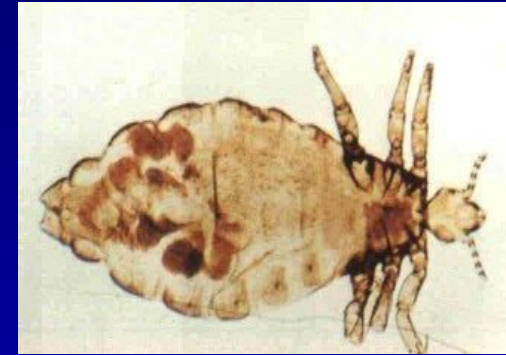
Localization: effect of individual
and mutual grooming.



Two louse genera in humans

Pediculus: *P. humanus* in humans,
P. schaeffi in chimpanzees

Pthirus: *P. pubis* in humans,
P. gorilae in gorillas



Pthirus pubis (crab louse = *muňka, filcka*)

Usually in hairs of genital region, sometimes in beard, eyelashes and underneath of arms, NOT on the finer hair of the scalp.

Females live up to one month and lay about 2 eggs daily.

Without blood die within 48 hrs. Eggs (nits) hatch after a week.

Itching, dermatitis (*maculae caeruleae*) in response to bite.

Close contact, usually sexual intercourse.

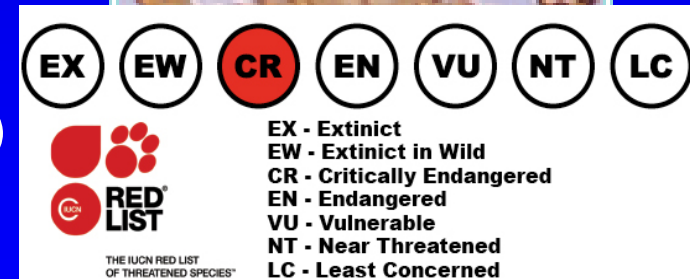
Adults and teenagers more frequently infested than children.

Non-sexual transmissions may occur among family and roommates (shared towels, clothing, beds or closets).

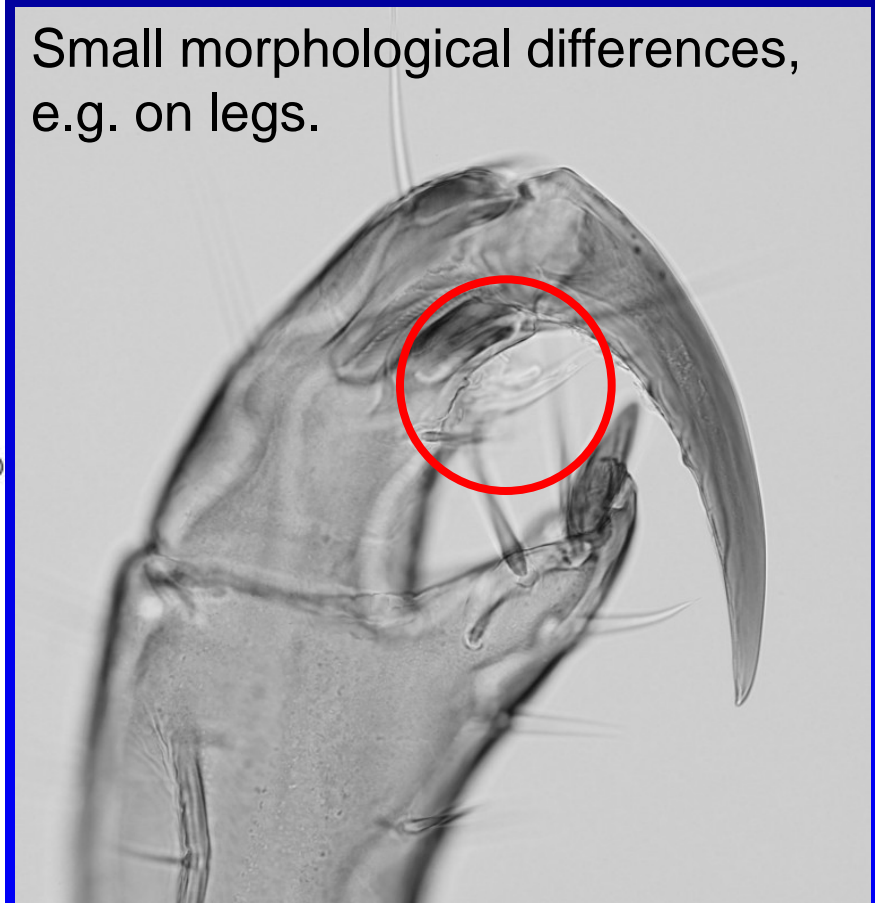
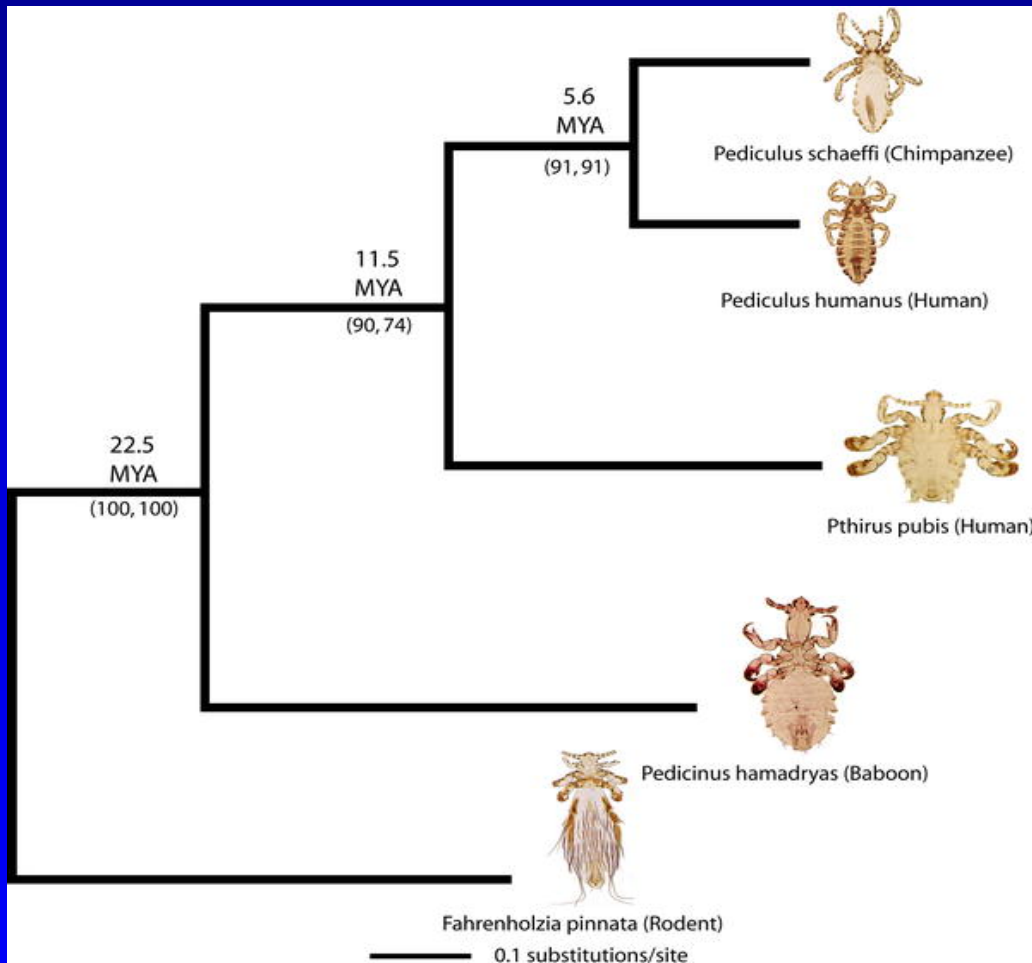
Insecticides: all effective (Orthosan H, Diffusil Forte, etc.)

repeat the treatment after 10 days.

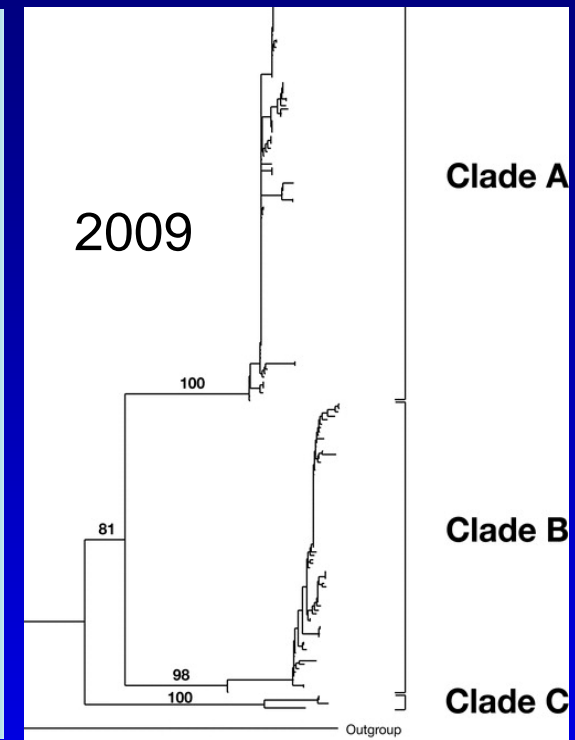
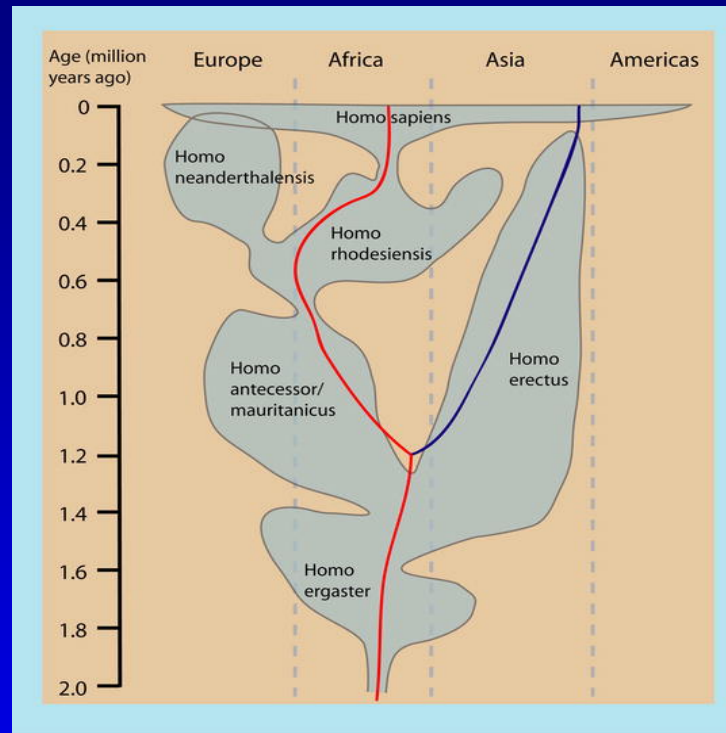
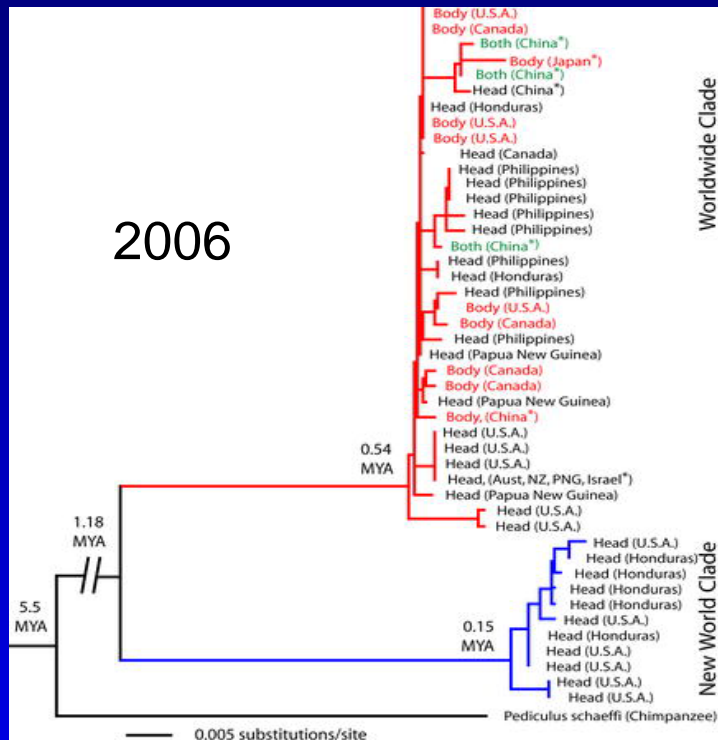
Effect of depilation: endangered species!!



Pediculus: in apes and humans, diverged 5-6 millions year ago.
 Two human subspecies of *Pediculus humanus* with different ecology: **ecotypes**
P. h. capitis (head louse) and *P. h. humanus* = *P.h. corporis* (body louse).
 Crossbreed in capture, not in nature. In laboratory on volunteers or rabbits.
P. h. humanus derived from *P. h. capitis* 50-100.000 year ago,
 at the time of the origin of clothing.



Hypotheses on *Pediculus* phylogeny



2006: two clades (mtDNA and nuclear DNA), one exclusively in the New World

2008: three clades, A all World, B: mainly America, C: Ethiopia, Nepal

2019: six clades (F in native tribes in Amazonia similar to *P. mjobergi* in NW monkeys)

Present: several mitochondrial clades exhibiting some geographic differences.

P. h. humanus found within clade A only.

Host switching of human lice to new world monkeys in South America

Head louse (*Pediculus h. capitis*)

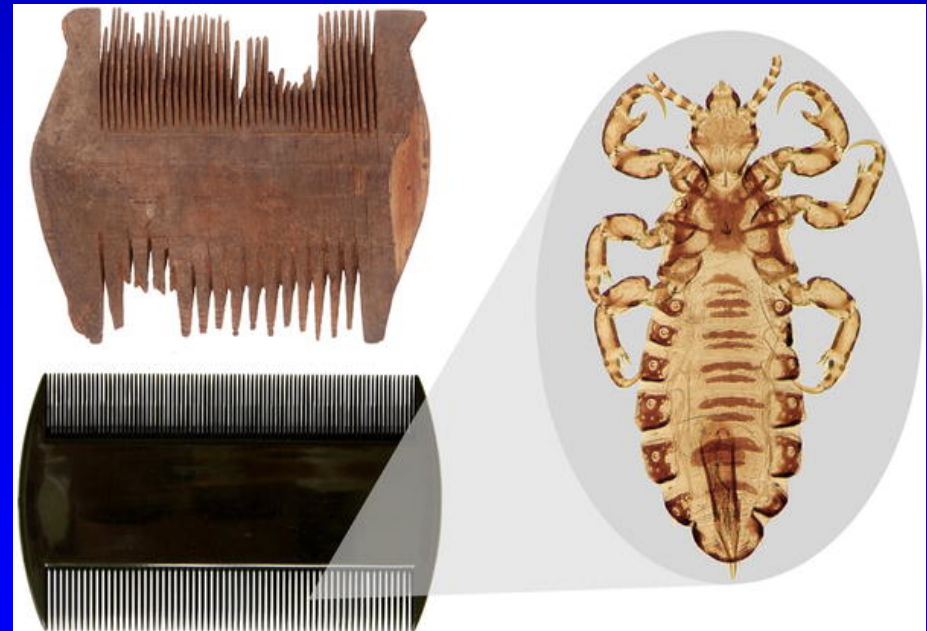
veš dětská = hlavová

On scalp, in hairs around ears, eggs glued on hair close to skin. Hair growing, old eggs more distant. Often less than 20 individuals (but massive infections accompanied by scars and secondary infections).

Mostly in children, hair length is not important, even in developed countries. Close contact, sharing combs, hats. In prehistoric times on hair combs (Israel, Peru).

Control: historically involved hair cut, petrolium, DDT, other insecticides. Resistance to pyrethroids. Diffusil H92M, Diffusil Forte (with karbamate) Recently mineral oils without insecticides.

Transmission of bacteria and viruses: experimentally yes but NOT in nature.





Mother hunting for headlice,
detail of a painting by Jan Siberechts



Body louse: *Pediculus humanus humanus*
(= corporis = vestimenti, veš šatní)

Live on the body, attach their eggs to clothes.
Life cycle 3-4 weeks. Females live up to month,
lay up to 300 eggs. All stages feed several times
daily, adults survive out of host about 3 days.
Development of eggs dependent on temperature.

Transmission by close contact, sharing cloth. Public
transport or cultural events (fertile female louse change
the host). **But** stable infestation is a result of low hygiene,
permanent use of the same cloth (prisons, war, disasters).
In Czech during the WW2 and after political changes in
90ties (refugees, homeless people). Dermatitis.

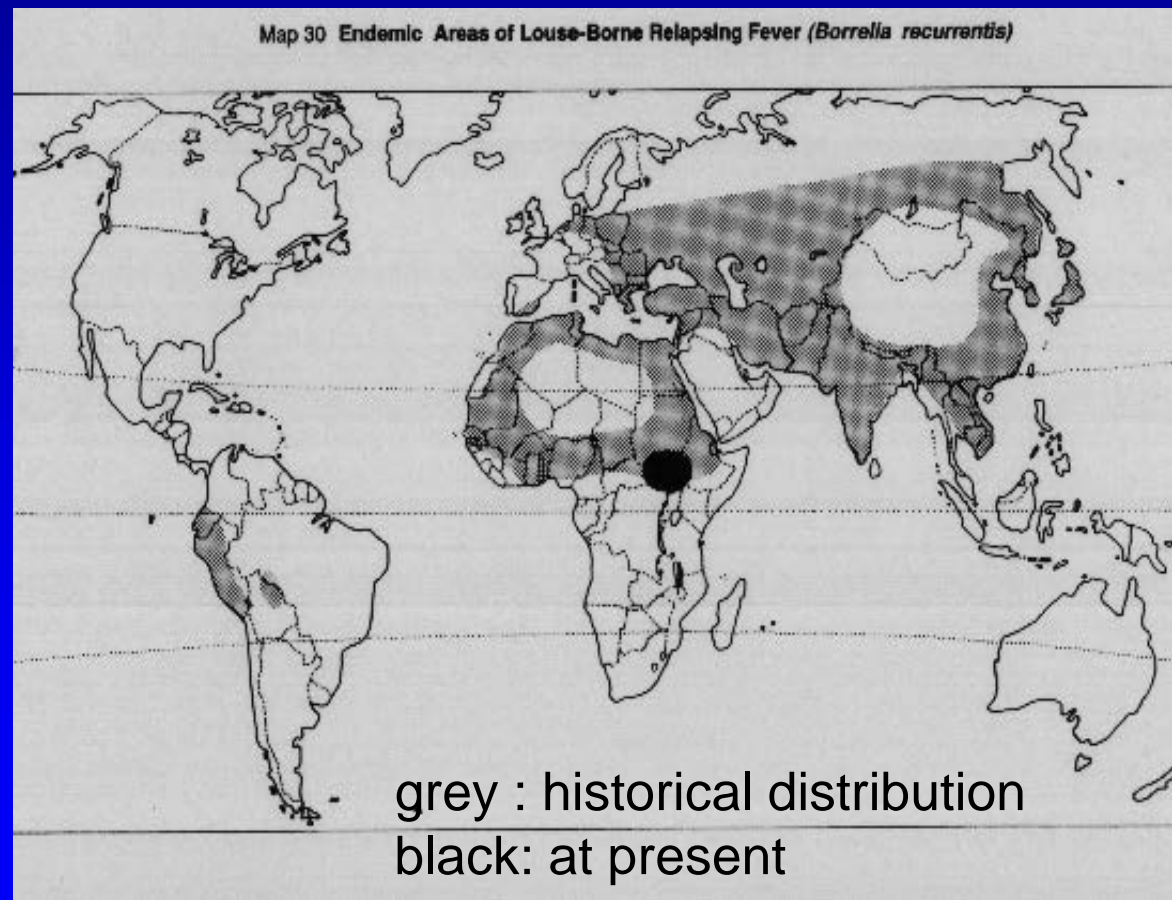
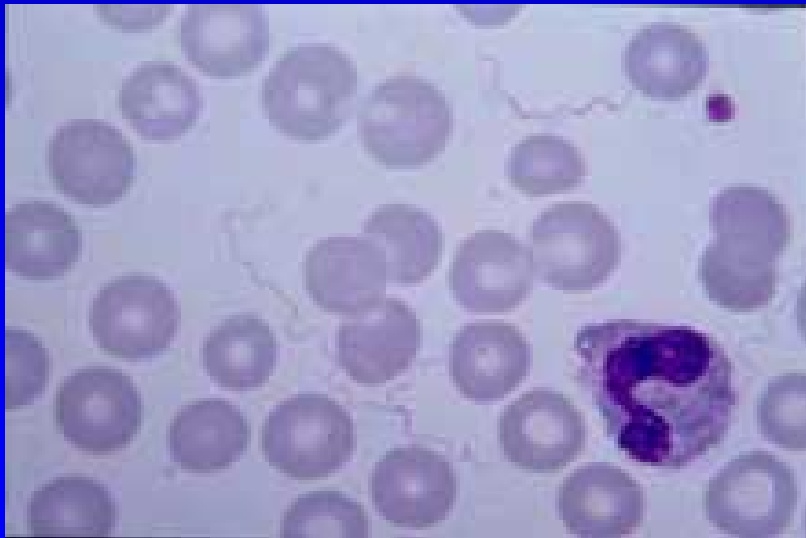
Control: change of cloth, washing (60°C), ironing.

Transmission: *Rickettsia prowazeki*, *R. quintana*,
Borrelia recurrentis



Borrelia recurrentis - causative agent of louse-borne relapsing fever

spirochaete, antigenic changes,
new subpopulation every 3-10 days,
Sporadic outbreaks in Africa, Ethiopia, Eritrea, Somalia.
Anthroponosis, mortality 30%,
affects liver and spleen.
Asymptomatic carriers.
Contaminative transmission:
crushing, chewing, eating.



Louse-borne rickettsioses (*P. h. humanus*)

R. prowazekii:

epidemic typhus, louse-borne typhus

Incubation period 3-30 days,

Several days of sustained high fever,
headache, muscle pain, chills, sensitivity to
light, rash in majority of cases, myocarditis.

Before antibiotic era mortality up to 70%.

Contaminative transmission: rickettsia in lice
feces, by aerosol, scratching of louse bites.

In louse transstadially, NOT transovarially.

Usually anthroponosis, but rodents as reservoir.

Carriers with Brill-Zinsser disease (reactivation of
rickettsia in endothelium). Doxycyclin.

WW1 and WW2, camps in Lety, Terezín, Bergen-Belsen

USA: rare sylvatic typhus, flying squirrels, their nests.

R. (Rochalimea) quintana: trench fever in WW1,
fever, headache, benign, in louse feces very resistant to
environmental conditions (months-year).



Map 29 Endemic Foci of Louse-Borne Typhus (*Rickettsia prowazekii*)



Amblycera (chewing lice)

Most „primitive“ suborder of lice.
Mandibles horizontally, small antennae in grooves,
long maxillary palps, most feed by chewing soft areas
of skin. Tarsi with two claws (bird parasites) or one
claw (parasites of mammals).
Many families, European exclusively on birds.

Menoponidae: on birds, feed on blood, chew new
feathers, important pests in poultry
Menacanthus stramineus, *Menopon gallinae*

Trimenoponidae:
on mammals in South America.
Trimenopon (and other two genera)
on guinea pigs.

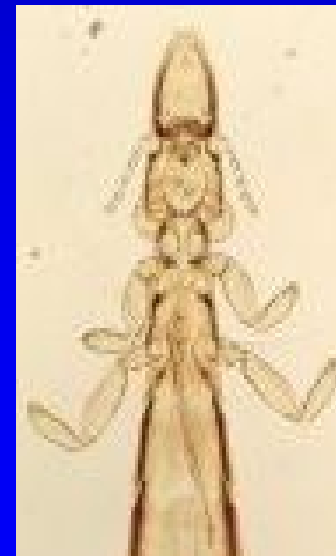
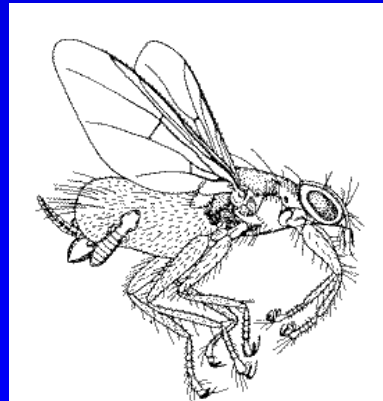


Ischnocera: (chewing lice)

Well developed antennae, mandibles vertically.
Mostly on birds, family Trichodectidae on mammals
Feed on the feathers and skin debris.
Veterinary important only in massive infections.
Many species, high host specificity.
Two main families, differ in hosts.

Philopteridae: parasites of birds.
Several species on the same host, different niches.
Many avian Ischnocera have an elongated body shape, e.g. *Columbicola*.

Trichodectidae:
parasites of mammals.
Damalinia bovis: dermatitis,
transmission by phoresis.

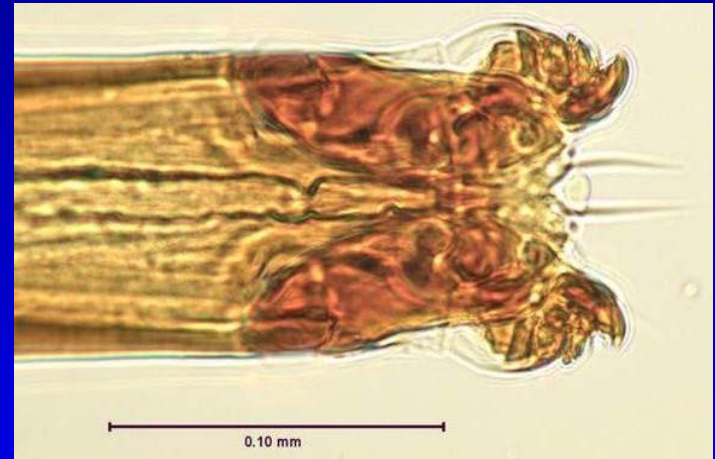


Rhynchophthirina

Mouthparts elongated to form long proboscis with terminal mandibles to penetrate the thick skin of their host.
Parasites of elephants and warthogs.

Haematomyzus elephantis
(elephant louse)
(1 - 2 species on elephants)

H. hopkinsi and *H. porci*
(warthog lice and red river hog louse)



Heteroptera: true bugs

Often with two different pairs of wings,
Some groups wingless, piercing mouthparts.
Predators, parasites of plants or animals (different salivary and digestive enzymes).
Five nymphal stages and adults.
Some predators, like Anthocoridae (Minute Pirate Bugs) may bite humans.
Three bloodsucking families:

Reduviidae: parasitic subfamily **Triatominae**

Cimicidae: all parasitic

Polyctenidae: small, specific parasites of bats,
About 30 species, both in Old and New World.



Cimicidae

Adults up to 5 mm, wingless.

Several genera, mostly in birds or bats.

About 90 species, various host specificity, some parasitizing under certain circumstances. In humans usually two species of genus *Cimex*.



Cimex lectularius: cosmopolitan

Cimex hemipterus: mostly in tropics

Minor morphological differences.

Traumatic insemination, asymmetric penis, mesospermalega (Berlese organ, thinner cuticula on sternit of 4th abdominal segment, spermatozoa migrate through the female's paragenital system to the base of oviducts.

Spread with furniture and by active crawling, bite during night, long-living, survive many months of starving.

Eggs laid in groups (maximum 200 during life), glued to the substrate (wall, furniture).



Cimicidae

Other species occasionally bite humans:
C. columbarius: chickens and pigeons
Cimex pipistrelli: trypanosomatids of bats
Oeciacus hirundinis: parasite on martins

Transmission: Not a single human disease. Experimentally hepatitis B but not HIV virus.

Direct effect: anemia, allergic reactions

Scent glands, characteristic odor detected in heavily infested sites. Dark fecal spots on bedding or bedclothes, pearly white eggs (1 mm long), and papery yellowish cast “skins” often found in cracks or crevices.

Control: Insecticides



KOUZLO LOŽNICE

»Garantol« kde, tam vesele
lehá manžel do postele,
lba rád — a očka mhouří,
po hospodě víc netouží!
Když v ložnici hmyz se rojí,
manžel doma neobstojí,
lépe mu je u sklenice,
než v noci tlouci štěnice!
K domovu jej nic nevděl
musí-li utloukat šváby,
chytat moly, honit rusy,
nechápe, kdo to nezkusí!
Proto každá moudrá žena
prostředkem jest zásobena,
po němž zhyne hmyz i mol,
a tím jest jen »Garantol«!

Při nákupu ve své drogerii žádejte jen ten
pravý Kobliskův „Garantol“, a to jen v původ-
ním plnění se záručovací páskou! Pravým „Ga-
rantolem“ zničíte pak snadno a jistě všechny
hmyz i zárodky trvale a uvěříte jistě pravdi-
vým slovům: Kde „Garantolu“ — není molů —
ani hmyzu! Ceny: „Garantol“ smrt: molů Kč
2:50, 5—, 10—, štěnice 7:50, 15—, švábů nebo
rusů 4:50, 10—, málč 5—, 12—, blech 5—, 11—,
mravenců 6:50, 14—, červotoče 8—, 19—, vši
8:50, 20—. K dostání jen v drogeriích, kde není,
zašle nenápadně od Kč 10— výše dobírkou:
Kobliska, drogerie „U slupce“ a „Garantol“
podniky, Praha-Smíchov, Štefánikova čis. 26.
Telefon 412-01. — Chraňte se padělků!

58

Reduviidae

Mostly predators of other arthropods, thick proboscis, extracellular digestion

Reduvius personatus: may bite you,
Last nymphal stage masked by dust particles

Triatominae (kissing bugs)

Subtropics and tropics, thin and telescopic proboscis, nocturnal, feed for 10-20 minutes, almost painless, 5 nymphal stages, long life cycle, from 3 months (*Rhodnius*) to half a year or more (*Dipetalogaster*).

Must fully feed during each instar

Feces: dark spots, contain aggregation pheromone
Copulation position „normal“.

Eggs with lid (operculum), dozens of eggs several times during life cycle. Laid freely (*Triatoma*) or glued to substrate (*Rhodnius*).

Up to 200-300 eggs in the lifetime.



Triatominae

Adults with two pairs of wings (1st one hemielytrae). Obligatory bloodsuckers
Hypersensitivity in repeatedly bitten hosts: density-dependent feeding success (and fertility, speed of cycle).

Starving bugs disperse. May feed on each other.

More than 140 species, mostly in the New World but *Triatoma rubrofasciata* is cosmopolitan in the tropics.

Triatomines feed on mammals, birds and reptiles.

The most important species are opportunistic (no feeding preferences), peridomestic, feed on domestic animals.

Different association with humans:

- : highly specialized forest species (unimportant)
- : attracted by light (*T. protracta*, may cause allergy)
- : originally forest ones but enter huts and chicken houses (many *Rhodnius*)
- : highly adaptable to human settlements (*T. infestans*, spreads to South, depending on human presence).





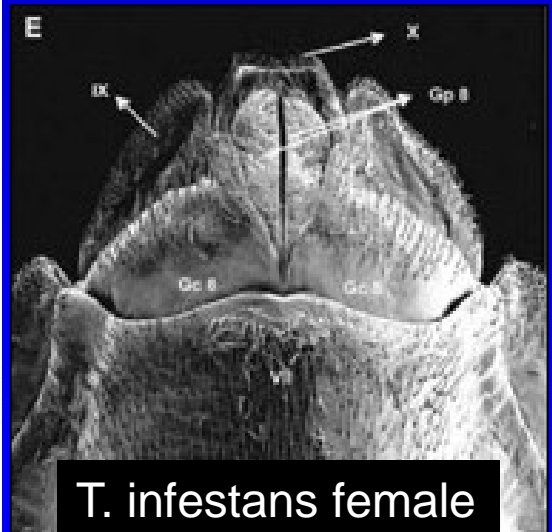
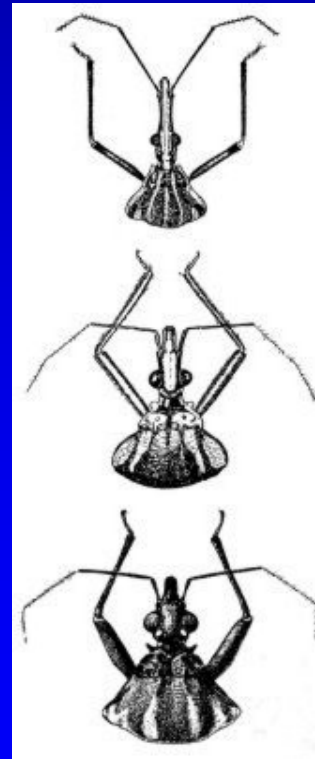
Morphology of Triatominae

Pair of compound eyes, adults also ocelli (behind eyes)
rostrum, pronotum, colored conexivum,
Sexual dimorphism only by external genitalia:
Tip of female abdomen pointed, while male
abdomen smoothly rounded (reflexed genitalia
covered by „cap“.
Local names, like „barbeiro“, „vinchuca“

Three most important genera: *Rhodnius*

Triatoma

Panstrongylus



T. infestans female

Triatoma

Mainly Latin America, semidry areas

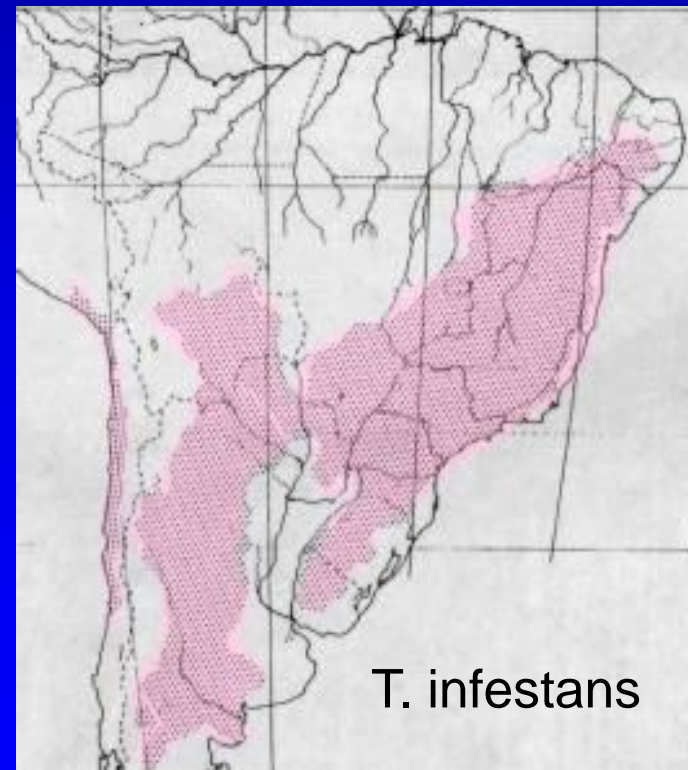
About 80 species, some important:

T. dimidiata: Central America

T. brasiliensis: Brazil

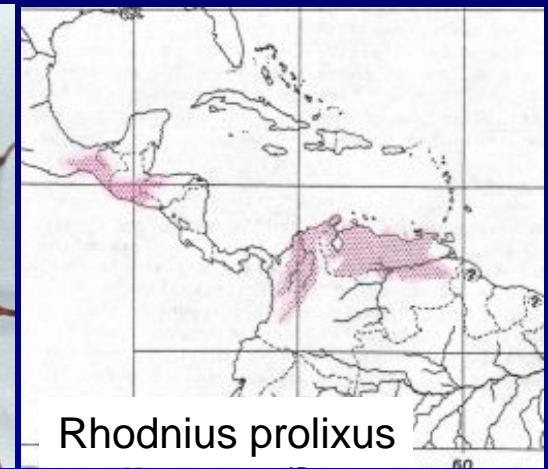
T. infestans : South America, originally in rodent colonies in Bolivia, spread with humans from NE Brazil to Argentina

T. rubrofasciata: tropicopolitan species



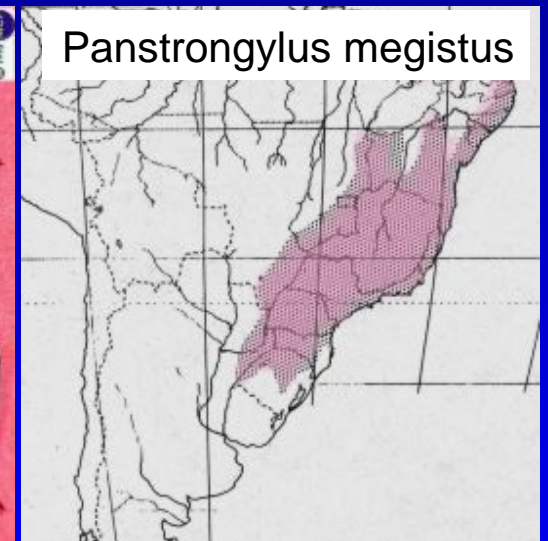
Triatominae: other important genera

Rhodnius (about 20 species):
Long rostrum, antennae far from eyes.
Mainly central America and Venezuela
R. prolixus a *R. palescens*



Rhodnius prolixus

Panstrongylus (about 10 species):
Short rostrum, antennae immediately in
front of eyes. Mainly Brazil.
P. megistus in humid areas



Panstrongylus megistus

Dipetalogaster maxima:
45 mm, big and dark, prefers reptiles
Nymphs of the 5th instar imbibe 3 ml
of blood



Importance for human and veterinary medicine

1. Anemia: dense populations, suck repeatedly

2. Allergy: *T. protracta* (Mexico, USA).

3. **Transmission of *T. cruzi*** (and *T. rangeli*):

Most species susceptible, only some serve as vectors,
must feed on mammalian reservoir
(*T. cruzi* lysed by bird complement)

High percentage of infected bugs,

Transstadial transmission (x *T. rangeli* transovarially)

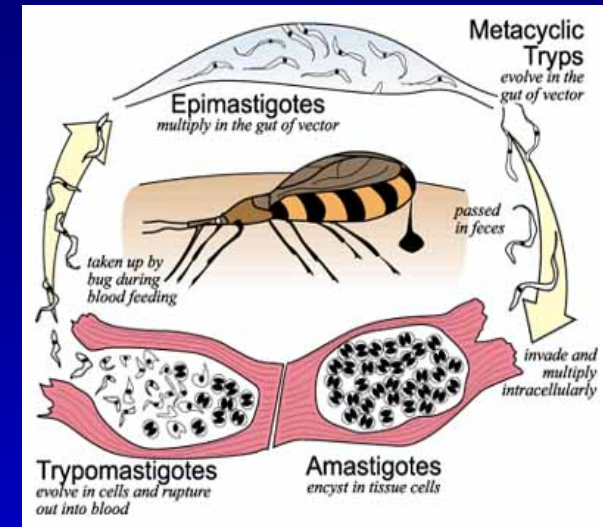
Contaminative transmission by defecation of bloodmeal
remains (defecate during the next bite).

Mucosa, conjunctiva, scratched into the skin.

Contaminated food or drink, blood transfusion,
transplanted organs, transplacenta.

Acute phase: fever, enlargement of lymph nodes,
mortality up to 10%, swelling (Romaña's sign)

Chronic phase: nervous system, digestive system
(megacolon), heart (myocarditis), autoimmune disease.



Diagnostics of Chagas disease: formerly xenodiagnoses (and through membranes). Now direct agglutination, ELISA, PCR. Blood and organ donors!

Distribution: Spread in 20th century due to increase of human population. Spread of *T. infestans*.

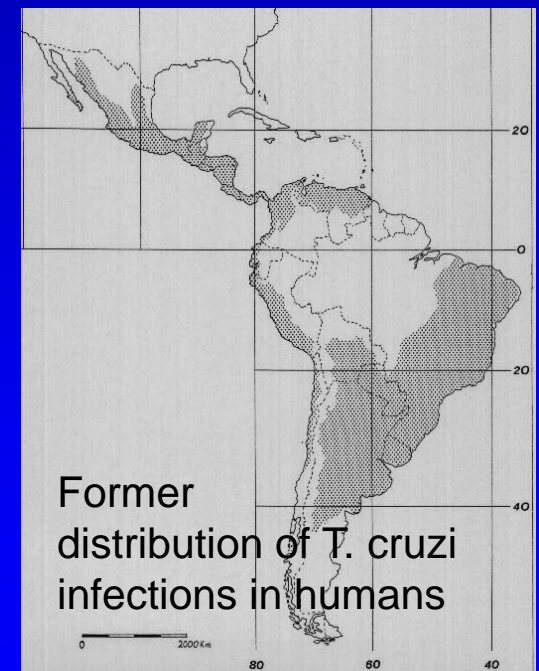
Prevention: improvement of living standards, hamacas, insecticide impregnated bednets.

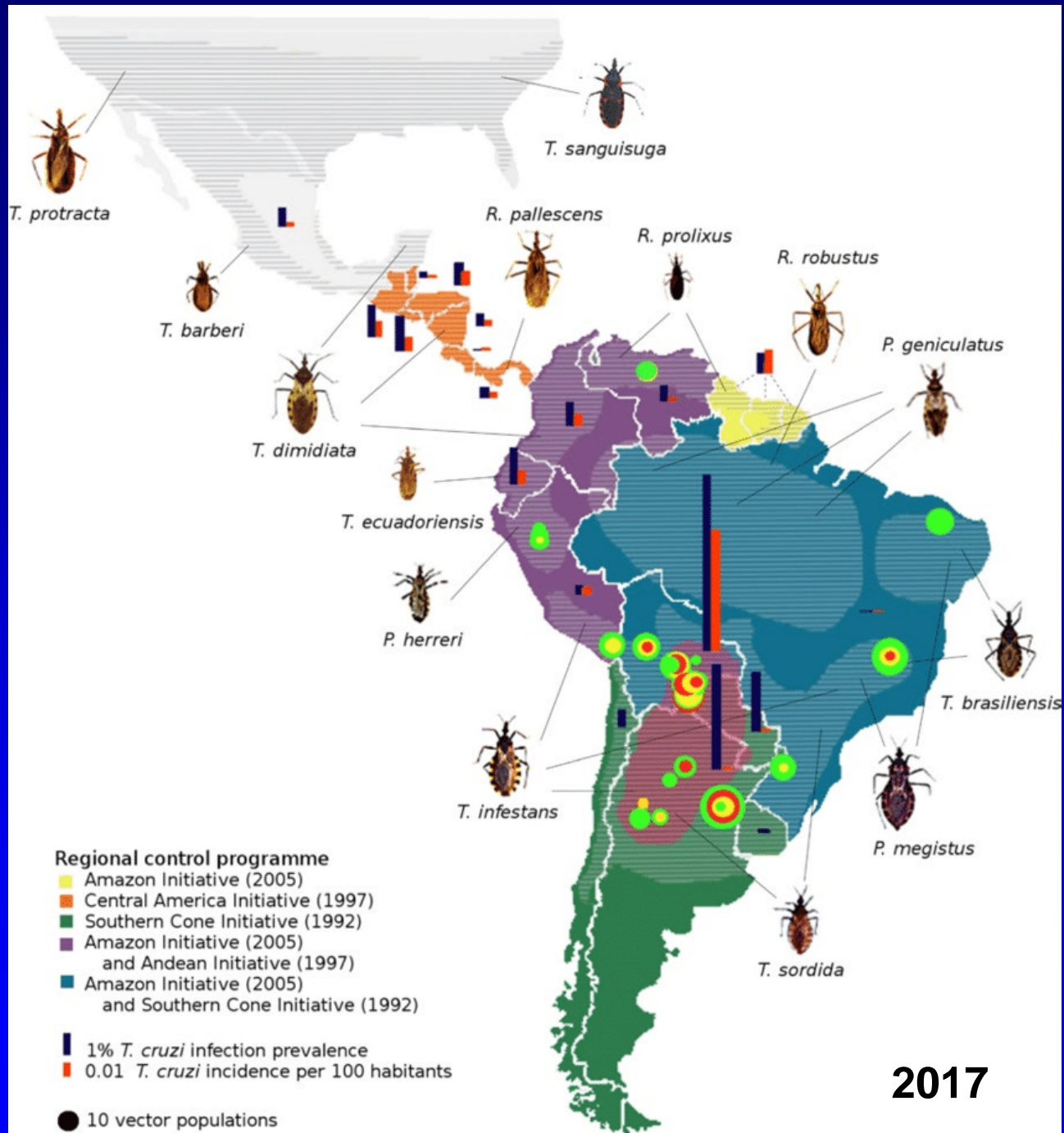
Vector control: chemical campaigns by synthetic pyrethroids, search for bugs, spraying all houses in the village, monitoring, eventually the second spraying. In 2006, urban and suburban areas of Brazil declared free of transmission by *T. infestans*.

Problems: continuation, peridomestic species (*T. infestans*) replaced by forest species (*Panstrongylus*).

Alternative: treatment of vector habitats with the fungus *Beauveria bassiana*.

Future: targeting the bug symbionts of through paratransgenesis? (*Rhodococcus rhodni* producing Cecropin A).





Aphaniptera (Siphonaptera) Holometabola (Oligoneoptera)

Phylogenetically close to Mecoptera (predators) genus *Boreus*



Fleas: 2500 species

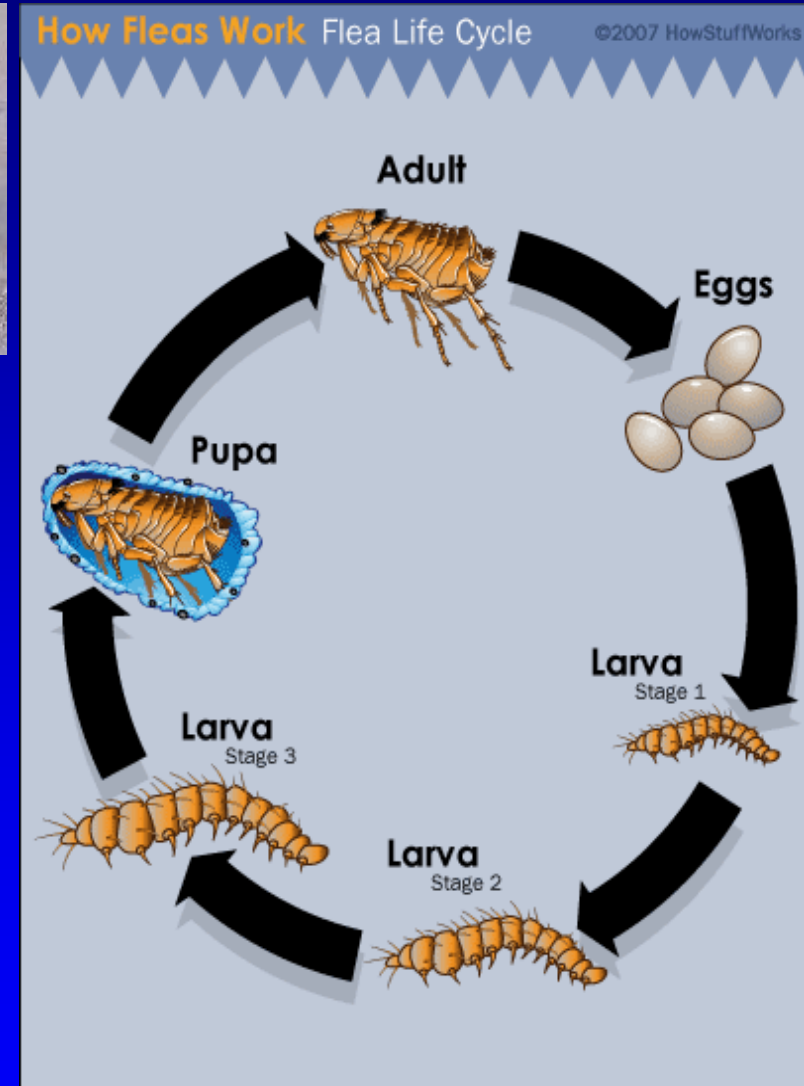
Adults: both sexes suck blood.

jump: resilin on 3rd. thoracic segment

Clutches of eggs (about 10 daily) into organic waste, larval development takes from 3 weeks till 9 months, adults live for up to 2 years.

Host „specificity“: adaptation to hosts living in the same niche, different fecundity on different hosts. Aphanipterium of squirrel, ground mammals etc.

Synchronization with the life cycle of the hosts (hormons? immunity?)



Pupa: in silk cocoon, covered by dust, protection against drying, young adults wait until host arrival (vibrations).

Larvae: with head capsule (eucephalic), three stages, hairs on each segment, feed on organic debris, feces of adults, small invertebrates

Adults: feed quickly

BUT!!!

Echidnophagidae

hen fleas or sticktight fleas.

About 25 species, birds, marsupials, rabbits etc. Females feed for prolonged periods of up to 19 days.

Anaemia, loss of condition, severe skin irritation, sometimes death.

***Echidnophaga gallinacea*:**

cosmopolitan: America, Africa, Australia, Southern Europe.



Jigger or chigoe fleas

Hectopsylla, *Tunga* (Hectopsyllidae)
Several species, one in humans.

Tunga penetrans

(sand flea, jigger flea, chigoe)

Tropical Africa, America, India.

Small (less than 1 mm), on mammals.

Reservoirs are domestic pigs and cattle.

Fast larval development in soil contaminated by feces or urine.

Mated females dig into the skin, usually in foot, abdomen grows to almost 1 cm.

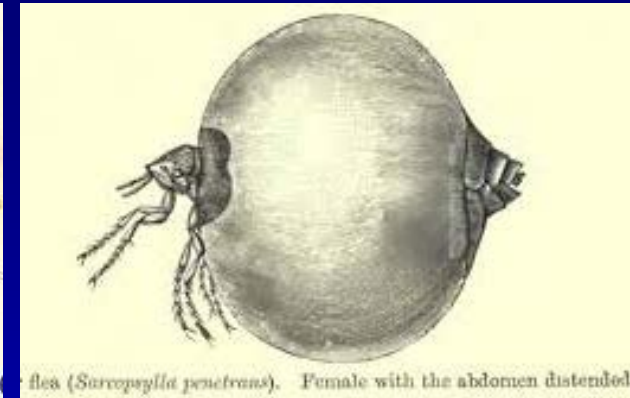
Posterior opening with rectum and genital openings, eggs out.

Tungiasis:

Inflammation, secondary infections.

Surgical removal, protection to sepsis.

Repellents, shoes.



Most common fleas in central Europe

In humans: 1 typical species, others occasionally

Pulex irritans: canid burrows, human dwellings

Ctenocephalides canis a felis:

Canids and felines, adults in host haircoat

Larvae in huts, dog and cat nests, cushions, blankets

Ceratophyllus (gallinae):

Dark fleas on birds, nests, treeholes and nestboxes.

Many genera common on small mammals:

Ctenophthalmus: on rodents

Archeopsylla: on hedgehogs, slow

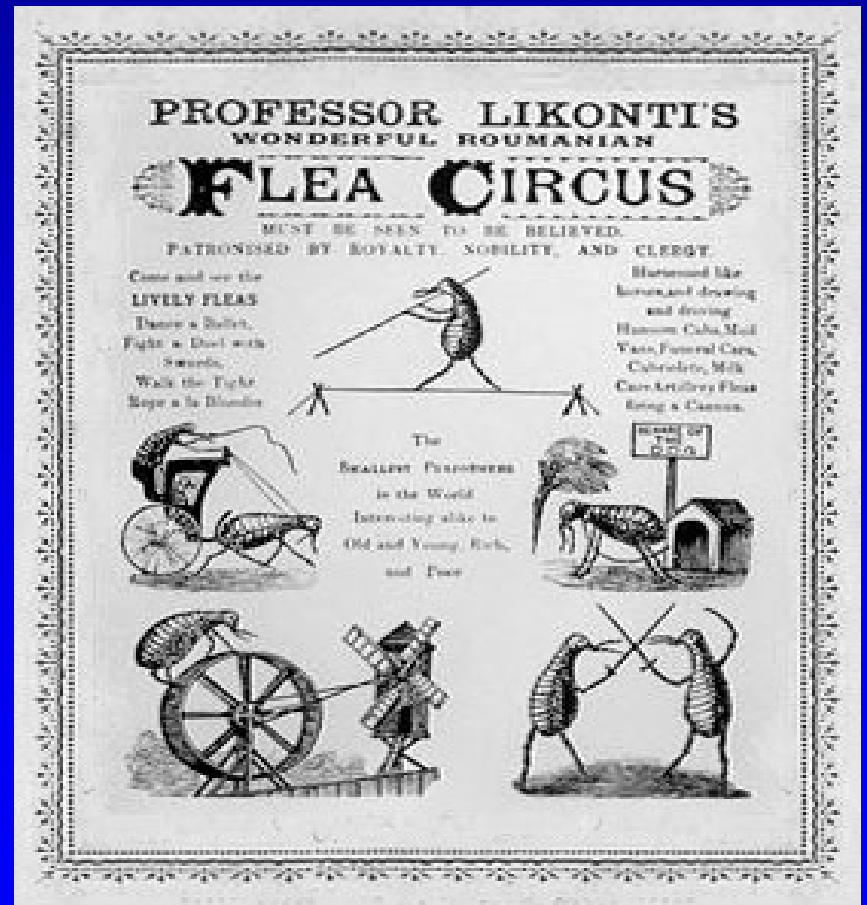
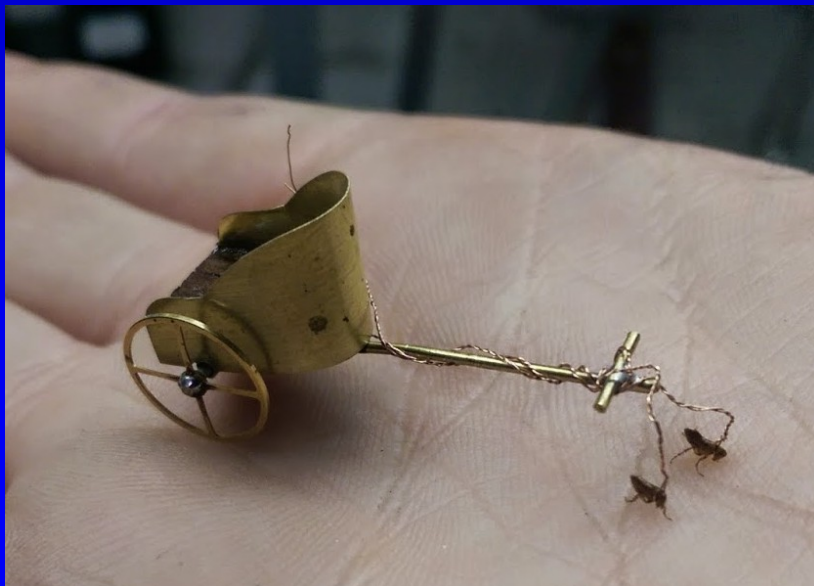


Medical importance

1. **Dermatitis:** pink or red spots, itch
Skin allergic reaction,
early and delayed hypersensitivity

2. **Chigoe fleas** (Tungidae =
Hectopsyllidae)

3. **Transmission of human diseases**



Flea-borne diseases

In humans mainly plague and flea-borne rickettsiosis

In animals myxomatosis and tularemia

Myxoma virus (*Fibromavirus*): contact, mechanical transmission by *Spilopsyllus cuniculi* and mosquitoes. Control of rabbit populations, from S. America taken to Australia (1950), France (1952-54) and Europe. Vaccine.

Francisella tularensis: although bites from ticks and handling infected animals are more common modes of transmission, the disease also is spread through ingestion of contaminated food or water, inhalation, and insect bites, rabbit flea *S. cuniculi*.

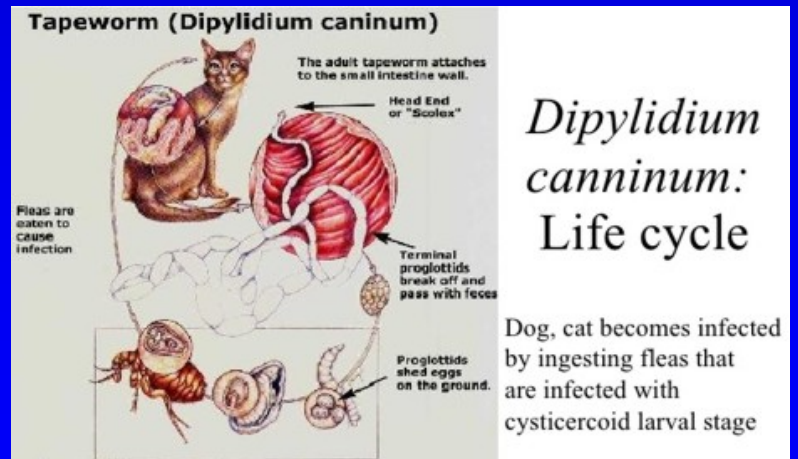
Intermediate hosts of tapeworms:

Dipylidium caninum: flea larvae ingest eggs, cysticercoid grows in larval hemocoel, transstadial transmission, hosts eat fleas
Similarly *Hymenolepis* (*H. nana* in humans, other species in rodents)

myxomatosis



Cutaneous tularemia



Human diseases transmitted by fleas: *Rickettsia typhi* (= *mooseri*)

(*myší skvrnivka*), murine typhus (endemic typhus) transmitted by *Xenopsylla*, *Leptopsylla* from rats and mice (reservoirs).

Transmission by bite or contamination by feces: stays infective for years.

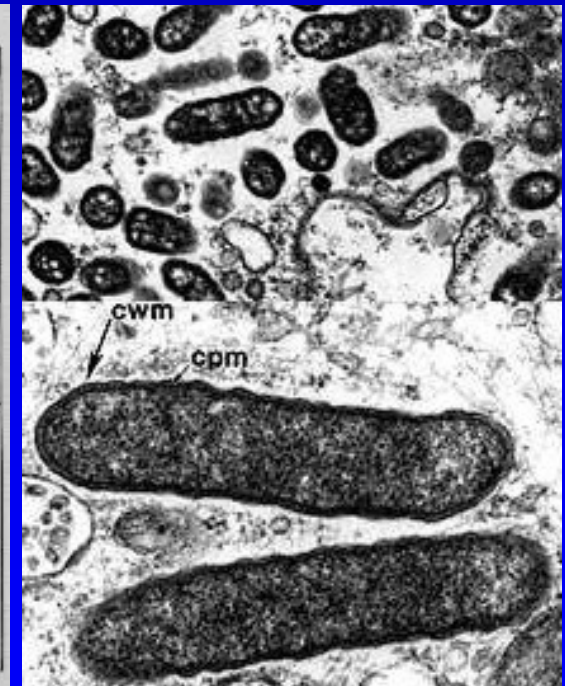
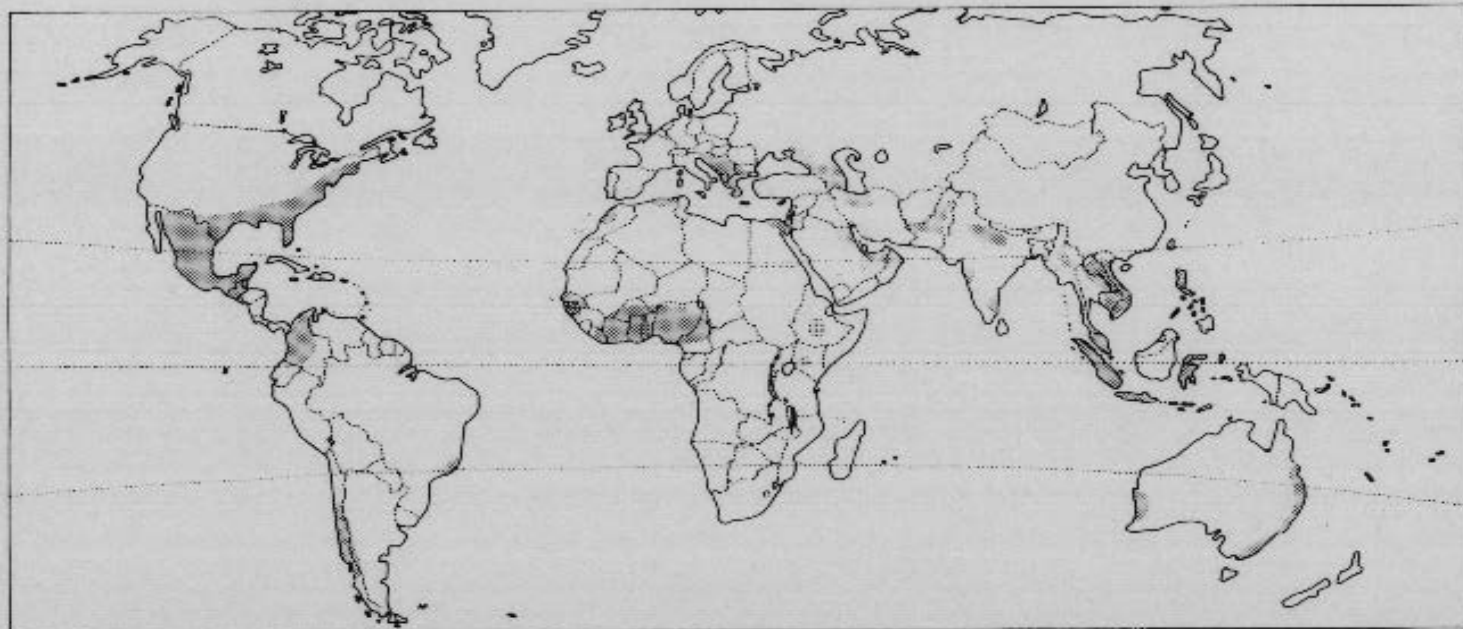
Symptoms include headache, fever, muscle pain, joint pain etc.

Cca 50% of patients develop a rash or neurological signs including imbalance.

Antibiotics tetracycline and chloramphenicol.

Death may occur in the elderly or immunocompromised patients.

Map 47 Distribution of Flea-Borne (Murine) Typhus (*Rickettsia mooseri*), Endemic Areas



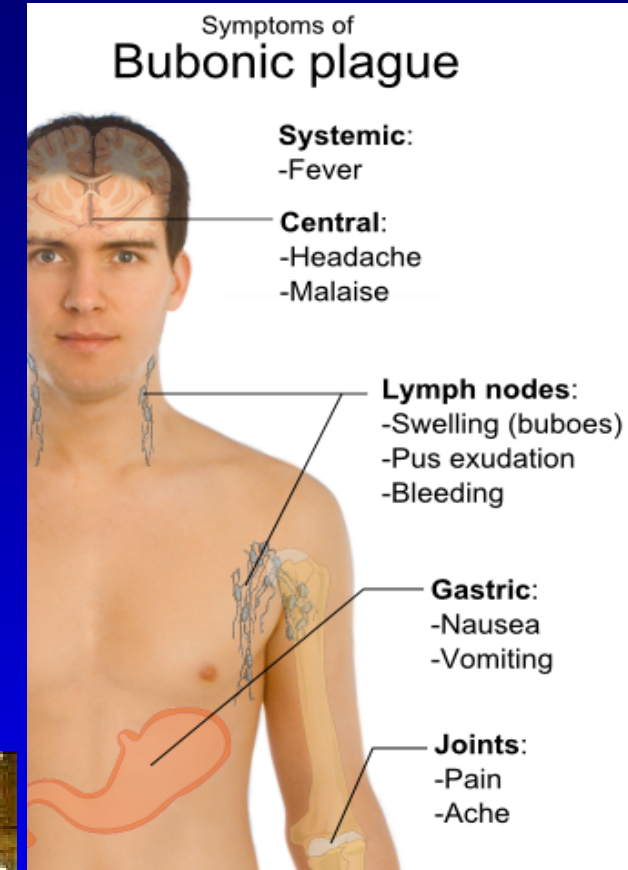
The most important flea-borne disease: Plague

Three main forms of the disease:

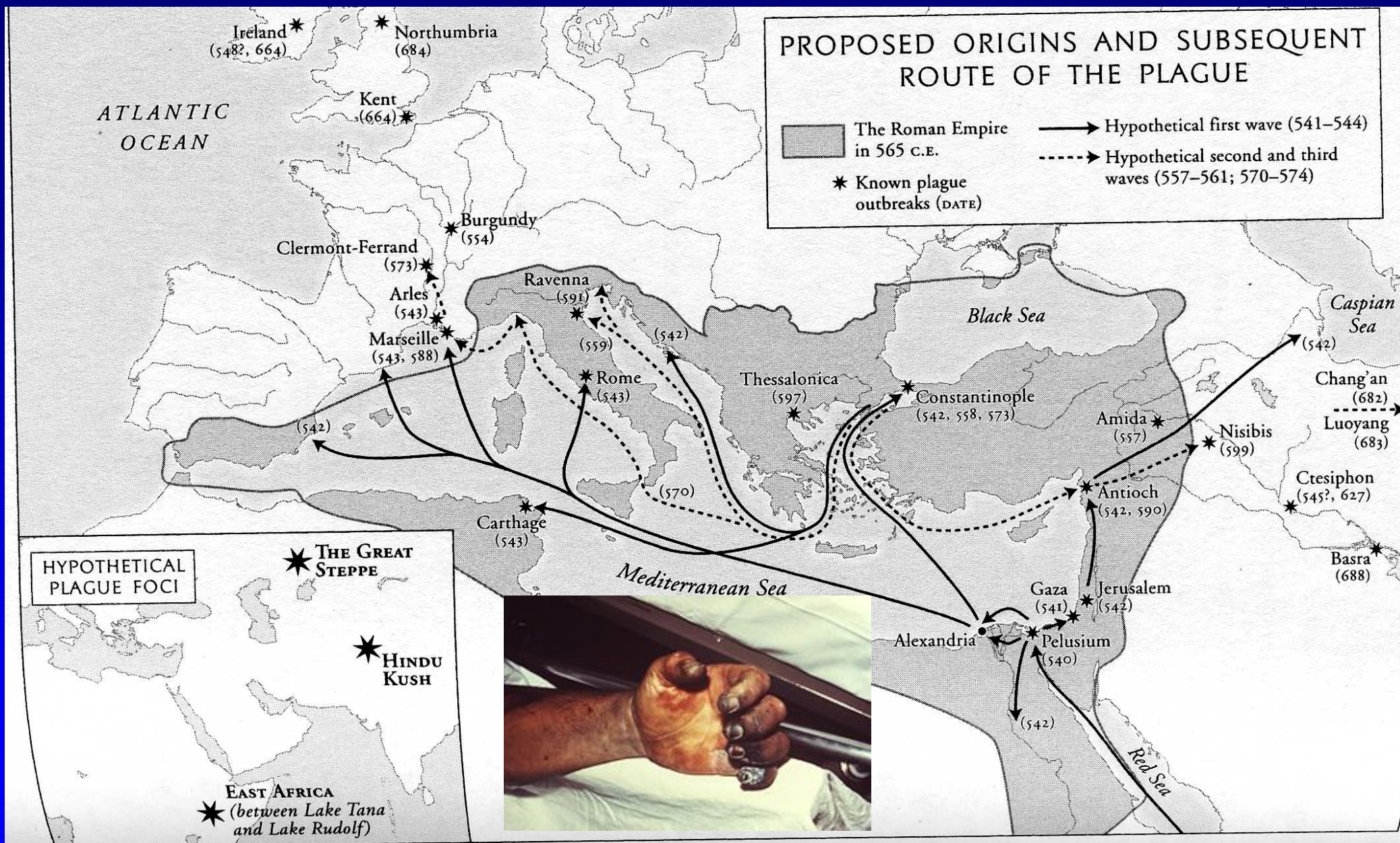
Bubonic plague: fever, swelling of lymph nodes.

Septicemic plague: bacteria released into blood, acute and fatal. Break of capillaries, intravascular coagulation, dark skin, necrosis (amputation), may enter lung and cause pneumonic plague

Pneumonic plague: inhalation of droplets, coughing up blood, from human to human, mortality rate from 90-100% if untreated. Streptomycin etc, in 24 hrs!



„Justinian plague“: First pandemic, followed trade routes in Roman empire

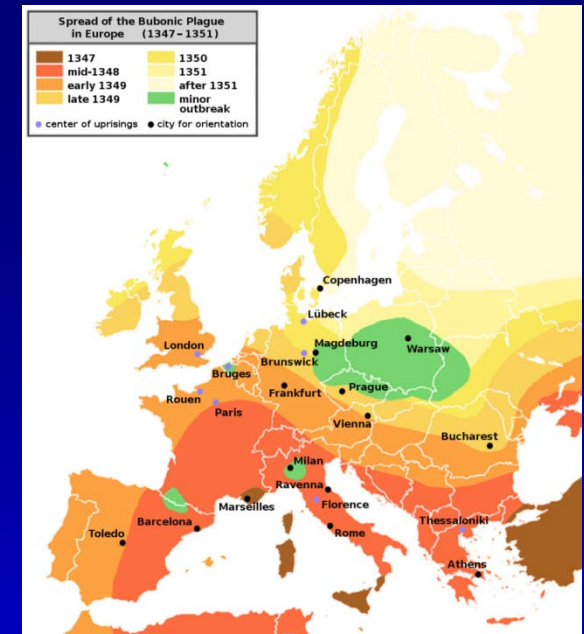


History of medieval epidemics: Black Death

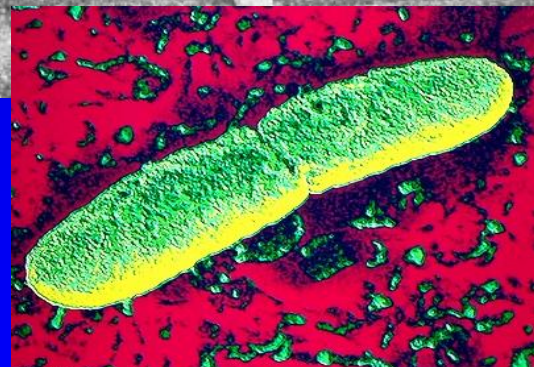
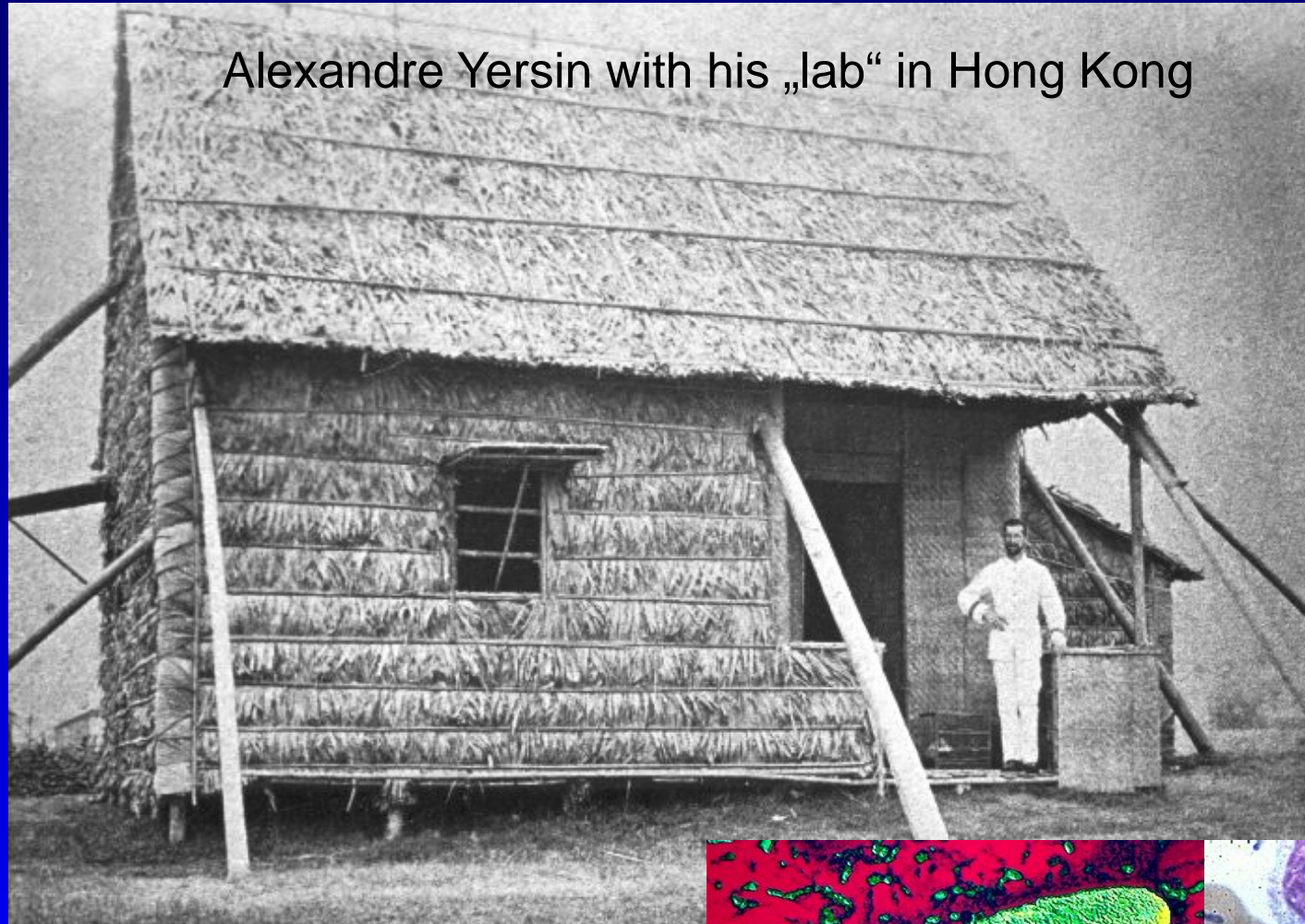
Introduced to Europe after First crusade (cca 1100).
 Second pandemic: 1347-52, mortality 15%-35%, then many epidemics in Europe:

year	mortality	place
1563-1565	10-30%	The Great Plague of London
1630-31	35%-69%	„Italian“ epidemic
1709-13	30%-49%	Germany, Northern Europe
1720	25%-50%	Provence
1743	60%	Messina, last European epidemic

Beginning of 20th century: Hong-Kong, then Third pandemic, 10 million dead in India. Yersin: *Pasteurella*.



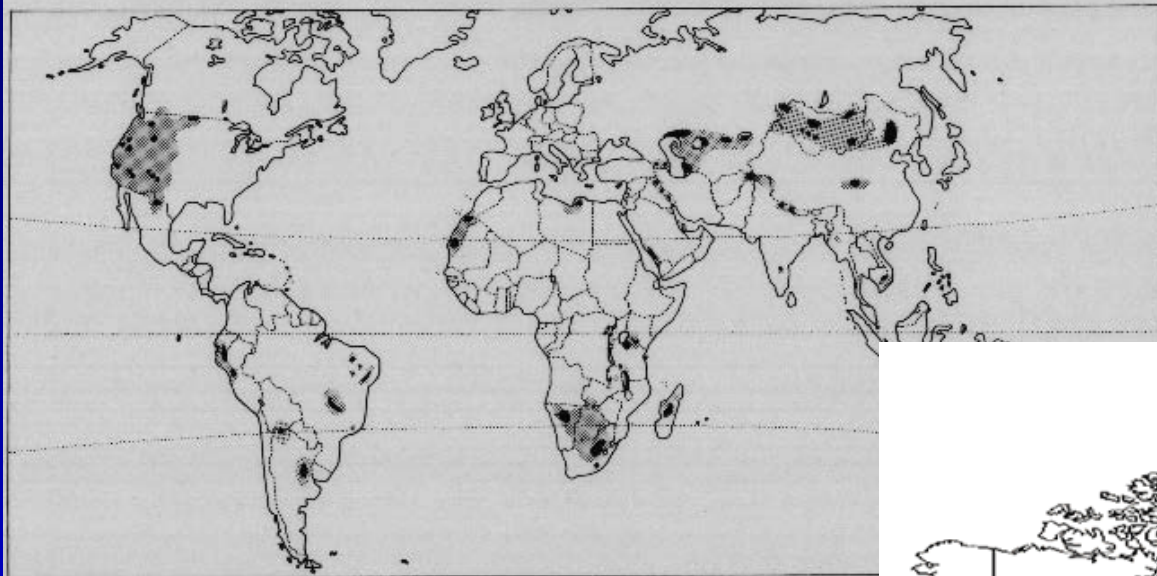
Alexandre Yersin with his „lab“ in Hong Kong



Plague bacteria in blood smear. Note safety pin appearance.

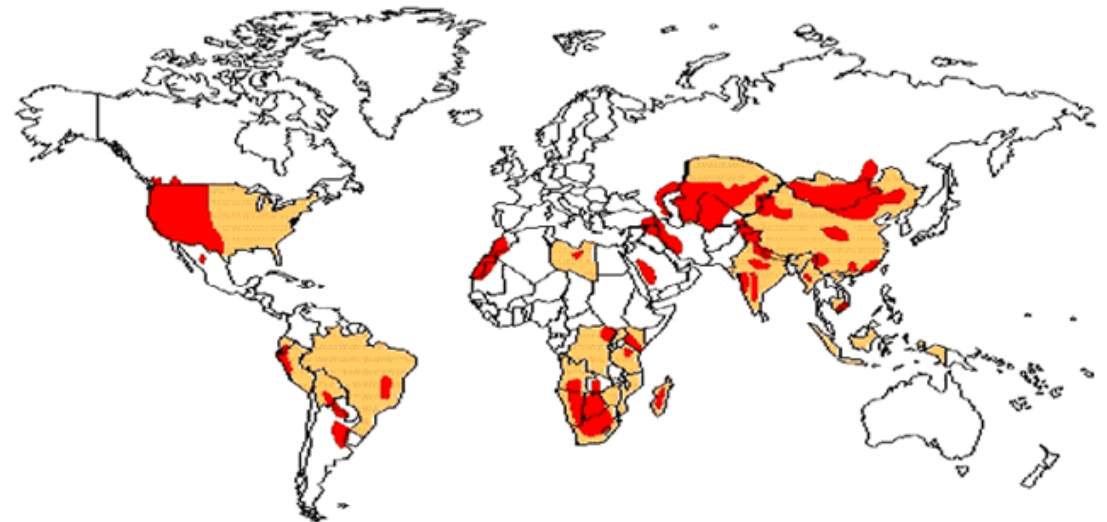
Centers for Disease Control and Prevention
<http://www.cdc.gov/ncidod/dvbid/plague/bacterium.htm>

Map 45 Known and Probable Foci of Plague Transmission



- Frequent transmission
- ▨ Infrequent or suspected transmission

World Distribution of Plague, 1998

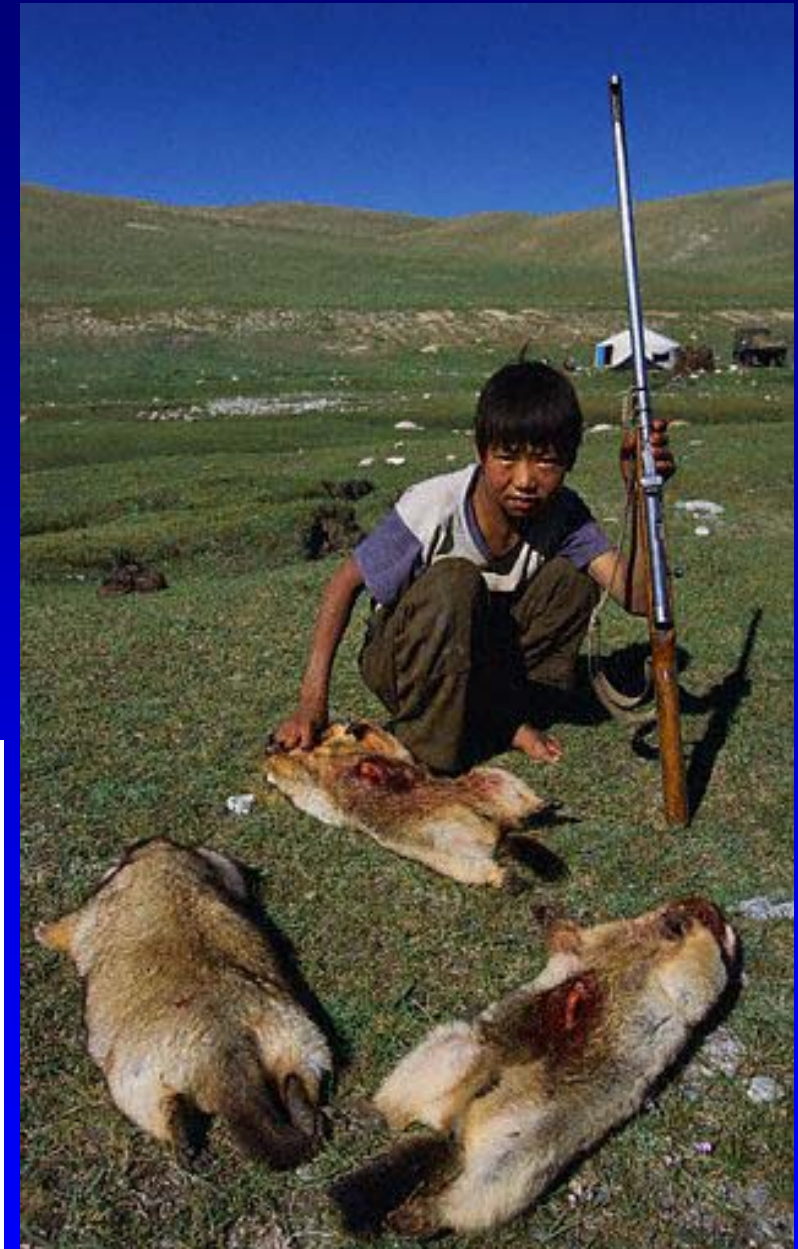
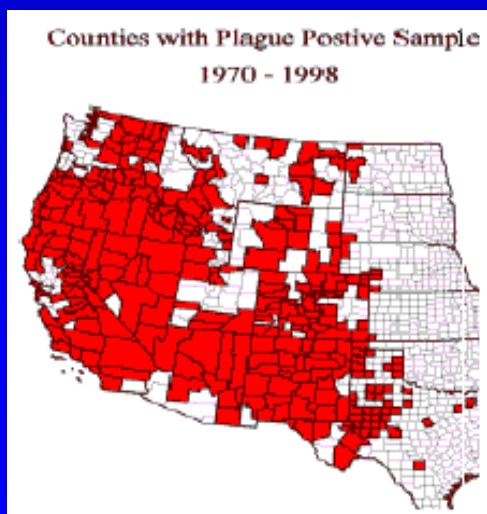


- Countries reported plague, 1970-1998.
- Regions where plague occurs in animals.

21st century: many contemporary cases, few epidemics with more than 100 deaths:
2006: Democratic Republic of Congo, 2013-14: Madagascar

Plague transmission

- A. Sylvatic foci: Rodents living in colonies (chipmunks, squirrels, marmots), cats etc. Direct contact, scratches, flea bites, inhalations from nests and burrows. Affects hunters, biologists.
- B. Urban foci: rodents and humans
Black rat *Rattus rattus* vs. *R. norvegicus*.
Flea bites, then pneumonic plague.



Vectors: more than 80 flea species (but not *Ctenocephalides*. USA: *Pulex* and others, Africa: mainly *Xenopsylla cheopis*, Asia: various genera

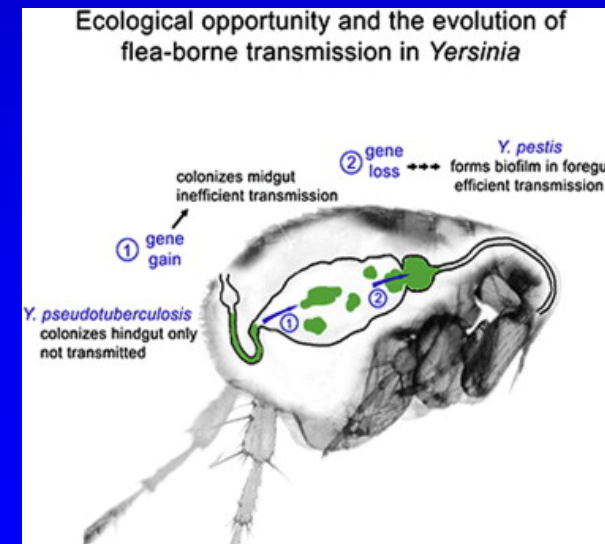
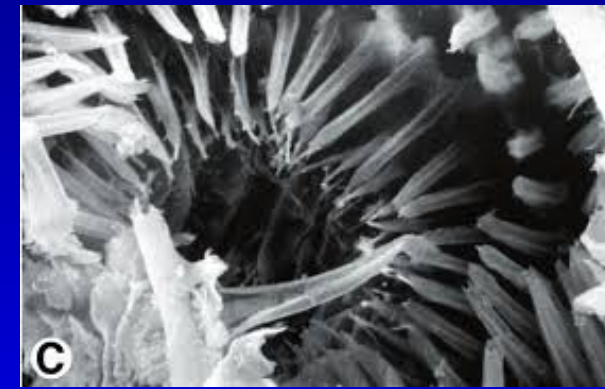
Mechanism of transmission

Proventriculus with densely packed cuticular spines. *Y. pestis* fill the lumen of proventriculus and partially obstruct the blood flow. Transmission by regurgitation.

Hypothesis about fibrin and fibrinolysin (28 °C x 37 °C)
More recently: *Y. pestis* recently adapted to flea-borne transmission (10.000 years).

Clonal variant of *Y. pseudotuberculosis* with 2 pestis-specific plasmids. Horizontal gene transfer, used for new functions:

- i. Phospholipase D: enables colonize the midgut
- ii. Hms (hemin storage locus): biofilm in proventriculus



Flea control and prevention

Find the source, remove fleas from hosts but also from the indoor and outdoor environment.

Adulticides (synthetic pyrethroids + nicotinoids)

Larvicides: insect growth regulators/development inhibitors pyriproxyfen or methoprene.

Combinations in the form of carpet powders, sprays.

Indoor mechanically, vacuuming (especially where your pet sleeps). Wash pet's bedding weekly, treat the bed and surrounding area with adulticide and/or an insect growth regulator. Clean other places your pet spends much time (car).

Collars with insecticides: long-lasting effect (months). Spot-on pipets: few weeks.

Deratization of reservoir animals. Insecticides, growth regulators into burrows of rodent food.

