

Ectoparasites

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Ectoparasites

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Fleas

General



Cat flea, *Ctenocephalides felis*, a vector of *Rickettsia felis*. Notice the combs, which gives the animal its name.



Human flea. *Pulex irritans*. © ITM

Fleas are cosmopolitan, wingless insects. They are obligate blood-sucking ectoparasites. They are not strictly adapted to a specific host and on occasions can bite unusual hosts, including humans. Although feeding on less than ideal hosts keeps the fleas alive, it reduces their fertility. The most important jumping fleas are *Pulex irritans* (the human flea), *Ctenocephalides* species (cat and dog fleas), *Xenopsylla cheopis* (Oriental rat flea) and *Tunga penetrans* (sand flea). Adult fleas live 6-12 and sometimes even 24 months. Fertilised adult females lay 3-18 eggs per day. After 2-14 days, depending on moisture and temperature, the eggs hatch to give very active legless larvae. Under favourable conditions, the larvae will pupate and emerge as adult insects. The cocoon is spun from sticky silk, so that a wide variety of substances become attached and provides camouflage. These pupae are therefore very difficult to detect. The pupa stage usually lasts 1 to 2 weeks. Sometimes the adult insect remains in the cocoon for a long time (up to 1 year). Emergence from the cocoon is

environmentally triggered (e.g. by proximity of a host: CO₂, heat, vibration). This explains why people who move into a house that has been empty for a long time can suddenly suffer numerous fleabites. Adult insects can remain alive for several weeks to months without feeding if the climate is not too harsh. Optimal conditions for their survival is high moisture and temperatures around 20°-30°C. Fleas leave dead hosts and this behaviour is important in the transmission and epidemiology of plague. Body temperature (37°C) inhibits the hatching of eggs and larval development. Reproduction occurs away from the host, on the ground, in cracks and in animal nests.

Muscles do not directly power the amazing jumps of fleas. Muscular tissue reacts too slowly. Instead, muscles are used to build up tension gradually. Fleas do not have wings but for their jumping, they use their wing stumps (their ancestors had wings). A hungry flea can jump up to 600 times per hour during three days. Fleas can jump 20 cm in height and 30 cm in distance. Bites are associated with the injection of saliva and cause a local pruritic skin irritation, principally on the legs. At night bites can occur over the whole body while people are lying down. These insects may be infected with the bacteria causing plague or endemic typhus (*Rickettsia typhi*) and *R. felis*. Other organisms can occasionally be transmitted. Fleas also transmit various sorts of minor tapeworms (*Dipylidium caninum*, *Hymenolepis diminuta* and possibly *H. nana*). Occasionally people develop long-lasting red skin lesions after insect bites. In such cases a Köbner's phenomenon due to psoriasis should be suspected. The original skin lesions themselves can be minimal (e.g. hidden on scalp, ear).

Simple hygiene is often sufficient to keep a house free of fleas. Insecticide resistance is increasing, including resistance to DDT. Organophosphates, carbamates and pyrethroids are used to eliminate flea infestation in a house. Pets can be washed with a shampoo with e.g. malathion or can wear a flea collar, i.e. a collar impregnated with dichlorvos. The latter provides a prolonged local vapour effect in the animal's fur. It should however be noted that most fleas are not present on the host, but in the bedding, on the ground, etc. For a cat with 25 fleas in its fur, there are some 500 adult insects, 500 cocoons, 3000 larvae and 1000 eggs present on the ground. Flea control should therefore also be directed towards the whole environment not just the animal. Cocoons are relatively resistant to insecticides.

Fleas, tungiasis

Tungiasis is a superficial infection of the skin by the sand flea *Tunga penetrans* (sarcopsilla; jigger flea; chique, do not confuse with chigger, which are trombiculid mites). *Tunga trimamillata* is a sand flea species identified in 2002 and seems to be limited to Peru and Ecuador. The lesions it causes are a bit bigger than those of *Tunga penetrans*.

With a length of about 1 mm (male and unfertilized female), it is the smallest known flea species. Both sexes live on sandy ground and bite birds and mammals, particularly pigs, but also dogs, cats, sheep, goats, cattle, horses, donkeys. Newly hatched insects are very active and the larvae jump around on the ground. They seem to prefer dry sandy ground. The insects don't do well in humid environments. The insects are a poor jumpers. The fertilized female bores into the epidermis and penetrates deep into the stratum corneum. The soles of the feet, the interdigital spaces and the skin under the nails are particularly affected. Any other part of the body that comes into contact with the ground can be infected (buttocks in beggars, children and lepers). The insect bores mechanically into the stratum corneum with the head innermost and bites onto the dermal papillae. The abdomen of the female swells as a result of the maturation of the approximately 200 eggs. After ten days the flea on average measures 1 cm in diameter. The hindmost abdominal segments are not distended and protrude out as a black central spot, through which excreta and eggs are released to the outside. After the eggs have been expelled the flea dies. The hole fills with fibrin and pus and is gradually re-epidermalised. After 3-4 days larvae emerge on the ground and pupate after approximately a week. The complete cycle takes 2-3 weeks.



Female Tunga penetrans under a toe nail. Photo Dr Van den Enden © ITM



Female *Tunga penetrans* burried in a finger, an uncommon site. Photo Dr Van den Enden © ITM

There is local pruritus and vague pain. In the beginning only a central black dot is visible. Later the lesion is raised, semi-transparent with a central dark spot and an erythematous halo. The number of parasites usually remains limited. However severe infestations with hundreds of sand fleas are found for example in leprosy patients, cachectic patients, alcoholics, in cases of advanced sleeping disease, in mental diseased and handicapped people or in confined communities.

Superinfection can occur during or after the primary infection, but particularly as a consequence of clumsy manipulation to remove the flea, as a result of which it breaks and parts of it remain deeply lodged. Lymphangitis can result as well as septicaemia and gas gangrene with a fatal outcome. Tetanus is a feared complication.

For treatment, the central opening in the stratum corneum is widened with a clean metal needle. The flea is removed and the remaining hole is disinfected. Prevention consists of wearing well fitting shoes instead of walking bare-foot or with wide open sandals. Socks that are left lying on the floor are to be avoided. Local basic hygiene is essential. Regular cleaning of floors using lots of water is strongly

advised, together with removal of pigs from the vicinity of houses. Affected areas of soil may be burned off. Ointment with cresol or lysol protects the feet.

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Lice

General

Lice (singular: louse) have parasitized humans since ancient times. While most primates have only one body lice species, humans have three (pubic, body and hair lice). According to genetic analysis, the common ancestor of headlice was shared by primitive hominids and primates until 6 million years ago. Pubic lice separated about 3 million years ago. Body lice are “only” 650,000 years old (coincides with the start of hominids wearing clothing). Lice have been found on Egyptian and pre-Columbian mummies and even on bodies dug up in Pompei. The Order of lice (Phthiraptera) is divided taxonomically into sucking lice (Anoplura) and chewing lice (Mallophaga), but there are alternative taxonomic classifications. Anoplura only parasitize mammals. Only three species of Anoplura are of regular direct medical importance to humans. These wingless insects are cosmopolitan, obligate haematophages and strictly adapted to their host (there is no animal reservoir). *Polyplax spinulosa* (Anoplura) is the sucking louse of rats and acts as an occasional vector of murine typhus. Only a single species of Mallophaga (*Trichodectes canis*) is known to have medical significance. *T. canis* is the chewing louse of dogs and acts as one of the larval hosts of the dog tapeworm *Dipylidium caninum*. This insect cannot live on man.

Pubic lice

Pubic lice (*Pthirus pubis*) do not themselves transmit disease. [The name *Phthirus pubis* is also used, but in 1987 the International Commission on Zoological Nomenclature decided to keep the original spelling of *Pthirus pubis*]. They occur on areas of the body with coarse hair (pubic region, perianally, sometimes also on legs, eyelashes, moustache, beard and even armpits and chest). Sometimes they are present on the scalp, including neonates. Sexual contact is the main method of transmission, but is not the only one (e.g. shared clothing). Any transmission involves bodily contact. They cannot live for more than 24-48 hours away from the host. If they are present in children, the possibility of sexual abuse should be taken seriously. A significant and strong correlation between the falling incidence of pubic lice infections and increase in pubic hair removal is observed. The increased incidence of hair removal may lead to atypical patterns of pubic lice infestations or its complete

eradication as the natural habitat of this parasite is destroyed.



Above: Pthirus pubis. Pubic louse. © ITM



Above: *Pediculus humanus capitis*. Head louse. © ITM

Body and head lice

Body and head lice (*Pediculus humanus corporis* and *P. h. capitis*) are two very closely related species (morphologically almost identical) but which occupy different ecological niches. The body louse *P. humanus corporis* lives in clothing and only comes onto the body to suck blood for a short time. The head louse *P. h. capitis* by contrast lives on the scalp and never on the clothing. Mutual fertilisation is possible in the laboratory, but in nature this appears not to occur and they are considered to be different species.

Fertilised females lay 6-9 eggs per day during their life. They live usually for 1 month, maximum 2. The animals are very sensitive to cold. The females attach the sticky eggs to underwear, shirts and trousers. Eggs on clothing cannot survive for more than 4 weeks (usually only 2 weeks). The eggs hatch after 6-9 days. Once hatched, the larvae suck blood five times a day, rapidly returning to the

clothing after each meal. Lice avoid light. Once adult, the animals will mate repeatedly. The reason for this is that females have no spermatheca and frequent mating is therefore crucial to build up a population. All in all this means that in optimal circumstances natural populations can increase by 10% per day. This is important in order to understand the dynamics of infections such as epidemic typhus and relapsing fever. Digestion of the blood is rapid. The red blood cells lyse. *R. prowazekii* infects the cells lining the intestine. The intracellular proliferation of *R. prowazekii* causes the insect's intestine to burst, spreading its contents into the haemolymph. The haemolymph will be stained red. The red colouration can be used in the laboratory to investigate whether a louse is infected with *R. prowazekii*. The louse dies from the infection with *R. prowazekii* and this fact was used previously to investigate which antibiotics were active against this bacterium. The antibiotic that enabled the louse to survive was then studied further. Lice are very sensitive to desiccation so that in dry environments they will not survive. Lice faeces are very dry and powder-like, with a water content of only 2%. The faeces contain a large amount of ammonium, which has an attracting effect on other lice.

P. humanus corporis can transmit *Rickettsia prowazekii* (epidemic typhus), *Bartonella quintana* (endocarditis, trench fever) and *Borrelia recurrentis* (epidemic relapsing fever). *R. prowazekii* is fatal for the insect after a few days. It is important for transmission and explains why people with louse borne typhus often have remarkably few lice. *B. recurrentis* proliferates only in the haemocoel of the insect and is transmitted by crushing an infected louse. This explains why "outbreaks" of louse borreliosis are rare unless there are massive numbers of lice. *B. quintana* can survive for up to a year in lice faeces.

The insects on clothing are destroyed by heat. For treatment, clothing is washed at 70°C, steam ironed or sterilised. In emergency situations (epidemic) insecticides are sprinkled (e.g. mixed with talc) between skin and clothing. Malathion or permethrin lotion or systemic ivermectin can be used.

***P. humanus capitis*.** This obligate bloodsucking ectoparasite feeds three to six times per day. The female lives one month and can lay up to 300 eggs, also known as nits. The eggs are deposited very close (approximately 1 mm) to the base of the hair and are firmly attached. Given that a hair on the scalp grows about 0.4 mm per day, it follows that virtually all nits found more than 5 mm from the base of the hair are either dead or empty (in practice a figure of 7 mm is taken). The egg shells of the nits are not removed by insecticides. Their presence after therapy sometimes causes anxiety and give rise to the mistaken belief that the insects are resistant.

Larvae and adults suck blood. The irritation from the bites can lead to chronic itching and scratching, possibly with secondary infection (e.g. impetigo) as a consequence. The insects are very dependent

on their host. Even fed adult lice cannot survive for more than a few days (maximum 10) without another feed. They leave a dead person or someone with high fever fairly rapidly.

Head lice treatment

There are several options: (1) wet-comb method, (2) topical organophosphate or pyrethroid insecticides, (3) topical dimethicone, (4) systemic ivermectine, (5) topical ivermectin.

In the wet-comb method the hair is first washed with a shampoo, followed by application of a hair conditioner to make the hair as smooth as possible. A good louse-comb has teeth 0.2 to 0.3 mm apart. The teeth should have an angular cross-section. After application of the conditioner, the hair is finely combed from the neck towards the front hair-line. The teeth of the comb should be in contact with the skin. After each movement, the comb is cleaned on a piece of white paper. When finished, the hair is rinsed, and combing is started again, this time from the forehead hairline towards the neck. This is done 4 times in a period of 14 days. If living lice are still found after this period, another therapeutic option should be used. The wet-comb method is time-consuming and cumbersome. The success rate varies from 37% to 57%. The advantages are low price, lack of resistance and it can be used when one prefers to avoid topical insecticides (very young children, lactating women). In olden days, shaving the hair very short was sometimes used.

Topical pediculicides. In most cases, infestation with lice is treated with insecticides, but head lice have become more and more resistant. Treatment options are organophosphates such as 0.5% malathion [Prioderm®, Radical®] or pyrethroids such as 1% permethrin [Nix®] or deltamethrin 0.66-1% in combination with 2.6-4% piperonyl butoxide (ParaShampoo®, Pyiderm®). The contact time should be sufficiently long: at least 10' for permethrin, 30' for deltamethrin and 12 hours for Malathion. Lotions are better than shampoos as they have a longer contact time with the hair. If after reapplication 7 days later, living lice are still found resistance is likely (reinfestation is also possible).

Dimethicone 4% (Silikom®) is applied to dry hair and is rinsed off 8 hours later. This is repeated after 7 days. The idea is to suffocate lice, cutting off the oxygen supply. The cure rate is about 70% with this method, although more study is needed.

Ivermectin is a neurotoxin acting on glutamate-gated and gamma-amino butyric acid-gated chloride channels. Oral ivermectin (Mectizan®, Stromectol®) can be used as an alternative or in case of multiresistant lice. A dose of 200 µg/kg is given twice with a 7-day interval. Studies showed a superior efficacy (95%) as compared with topical 0.5% Malathion lotion (85%) applied with the same interval. A 0.5% ivermectin topical lotion can be applied to dry hair, left for 10 minutes then rinsed with water.

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Mites

General

Mites are related to ticks, scorpions and spiders. In contrast to insects they do not have antennae and their body is divided into two rather than three parts. Larvae have 6 legs and adult animals 8 legs. Mites tend to be much smaller than ticks. These animals occupy the most diverse ecological niches from *Varroa* mites which are found in the respiratory tract of honey bees to *Demodex* mites which colonise the sebaceous glands of human eyelashes. In humans ***Dermatophagoides pteronyssinus***, is known as house dust mite. ***Sarcoptes scabiei*** causes scabies.

Some mite larvae belonging to the genus ***Leptotrombidium*** (belong to the harvest mites) transmit *Orientia (Rickettsia) tsutsugamushi* (scrub typhus) in Southeast Asia. Adult mites are of no direct medical importance as they feed exclusively on small invertebrates and insect eggs. A female lays 1-5 eggs per day on moist ground. After the larvae appear, they begin to crawl around actively on the ground, grasses, low plants, etc. Larvae attach themselves to a host when it passes through the vegetation and seek out a piece of skin that is soft, smooth and not too thick (peri-anal, groin, ankles). The very small larvae (150-300 µm) inject saliva and suck up the digested tissues. After 2-10 days the mites fall to the ground and dig themselves in for further development. The ecological habitat of these parasites is strictly defined. Optimal moisture of the soil, the right vegetation and sufficient hosts for the nymphs and adults (arthropods of various kinds), as well as the larvae (mostly rats and mice) need to be present. This results in a very scattered distribution and the existence of mite islands. These are areas where intense transmission of scrub typhus occurs, whereas no infections occur in places only a few kilometers away for instance. Although the potential zoonotic reservoir is not yet completely established, it is important to know that *Leptotrombidium* mites themselves serve as a reservoir for *Orientia tsutsugamushi* (transovarial transmission). Transmission of this kind can persist for several successive arthropod generations.

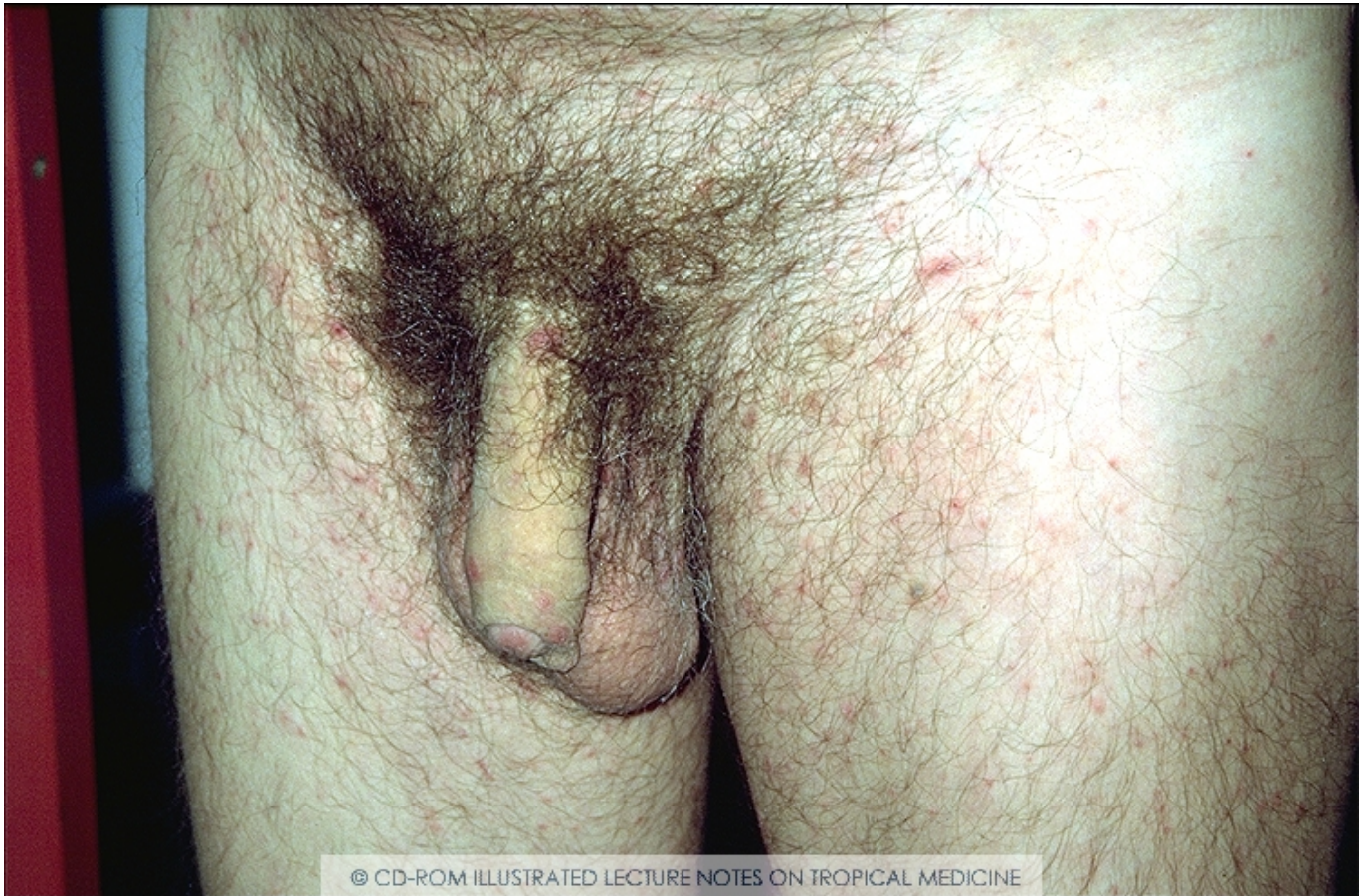
Scabies



Norwegian scabies on a foot of an AIDS patient. Copyright ITM



Norwegian scabies in HTLV-1 patient. Copyright Alexander von Humboldt Institute, Peru.



Scabies, genital nodules. These nodular lesions tend to disappear more slowly than other scabies lesions. Copyright ITM

Scabies is caused by *Sarcoptes scabiei*. Morphologically similar mites are found on various animals (in dogs *Sarcoptes scabiei* var. *canis*) but do not permanently infect humans. Cat scabies is caused by *Notoedres cati*. "Milker's itch" is caused by *Sarcoptes bovis*. *Sarcoptes equi* occurs in horses and riders can suffer an itchy skin disorder from these mites. Scabies mites do not transmit any pathogenic organisms. Adult female *Sarcoptes scabiei* mites measure 400-600 µm, while the smaller males are slightly more than half this size. The cycle from egg to egg lasts 10 to 14 days.

Human-to-human transmission occurs directly or indirectly when hygiene is poor. The majority of mites are found on the wrists and fingers, with smaller numbers on elbows and elsewhere. The face is practically always spared. The mean number of female mites per infected person is 11, most having 1-15 mites. Only 3% of patients have 50 mites or more. The mites dig burrows in the stratum corneum of the skin (1-5 mm per day). These tunnels are clinically very different from larva cutanea

migrans. A female lays 1-3 eggs per day in her tunnel. Besides the eggs, mite faecal matter (scybala) is present in the tunnels. Larvae appear after 3-5 days. These crawl on the skin surface and many die there. Another 5-6 days later the adult appears which remains in situ if it is female. After becoming an adult and fertilisation by a passing male, the cycle can begin again. Female mites live on a person for 1-2 months. A female can produce up to 40 eggs in her life. Scabies causes pruritus, particularly at night. A definitive diagnosis is not straightforward as the characteristic skin tunnels usually only become visible after secondary infection or eczematous reaction. Scabies may trigger “unusual” impetigo (*Streptococcus pyogenes*). Repeated application of corticosteroid cream can lead to masking: “scabies incognito”.

Scabies provokes a papular, pruritic skin rash. There will be itching at sites where the mites themselves are found (e.g. between the fingers, wrists, elbows, genitalia). The rash is also seen on parts of the body that are not infested by scabies mites. Buttocks, groin, shoulders, arms, calves and ankles can become itchy. In classic scabies, the rash almost never occurs on the head, palms of the hands or soles of the feet. The rash is caused because the patient has become hypersensitive to mite allergens. In a patient who has never been exposed to scabies the rash usually occurs 4-6 weeks after infection. In previously exposed people it occurs much more rapidly, sometimes within just a few days. Despite effective treatment, symptoms and lesions of scabies can persist for weeks (e.g. scabies nodules on the scrotum and penis). Hypersensitivity to the scabies mite does not disappear immediately after the death of the parasite.

Sometimes **Norwegian scabies** occurs (“crusted scabies”). This condition is clinically totally different from classic scabies. A clinical description was first given in 1848 by Danielssen and Boeck in Norwegian leprosy patients. The condition occurs more frequently in immunosuppression e.g. AIDS and in infection with HTLV-1 than in the general population. Drug-induced immunosuppression, long-term topical steroid use and to a lesser extent a mental handicap such as Down’s syndrome increase the risk. In Norwegian scabies there are very numerous mites present in desquamating hyperkeratotic skin crusts. The latter can also occur on the face. The disorder is highly infectious. Sometimes tinea pedis, psoriasis, severe dyshidrosis, hyperkeratotic eczema, contact dermatitis or Darier’s disease (keratosis follicularis; autosomal dominant inheritance) resemble it. In case of doubt, it is sufficient to examine some skin scales after treatment with 10% KOH under a low magnification microscope.

Scabies mites as yet exhibit no resistance to lindane or benzyl benzoate. For treatment, 20-30% benzyl benzoate is used, with which the whole body (except the face) is rubbed twice after washing with soap for 3 days. Lindane lotion (Quellada® = gamma-benzene hexachloride) can also be used but its use has been phased out because of toxicity concerns. This should be repeated after 7 days as the eggs are not killed by only one application. Pyrethroids are effective (e.g. 5% permethrin

(Zalvor®). Malathion is best used as a lotion not as shampoo. Crotamiton (Eurax®) is also sometimes used but is less effective. Oral ivermectin (Mectizan®) also produces relatively good results, but should preferably be repeated after a few weeks. It is the first choice in Norwegian scabies. Linen and bedclothes are disinfected at the same time by water at $>60^{\circ}\text{C}$. Washing bedclothes and clothing and ironing them with a steam iron during this period will also help break the cycle of transmission. Without access to a body the mites survive less than 4 days.

Guidelines for elimination of scabies in institutional outbreaks

- change encasings of mattresses, carpet, clothing
- cleaning rooms, furniture, couches
- topical and systemic treatment of patients (permethrin and ivermectin)
- synchronous topical treatment of all contacts with or without skin lesions
- clip nails, brush subungual folds with scabicides
- reduce social contacts, e.g. no reunions in nursing homes
- avoid pets, examine pets
- ten day quarantine of index patient
- caregivers should use gloves and protective clothing, alcohol and handwashing
- evaluate two weeks later for eventual retreatment

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Ticks

General

Ticks are small animals related to mites, scorpions and spiders. Ticks are also known as Metastigmata. Ticks differ from insects. Their bodies are divided into two parts rather than three. Ticks do not have antennae nor wings. The adults have eight legs instead of six. Ticks have 6 legs in the larval stage (nymphs and adult ticks gain a pair of hind legs). Ticks that have climbed onto grass or other plants become aware of their potential host by vibration, warmth, CO_2 , moisture and smell (all mammals secrete butyric acid). They remain attached to feathers, fur, skin or clothing, after which they seek a suitable place to suck blood.

There are two types of life cycles. In some species of tick, the larva, nymph and adult remain on the same, individual host not dropping to the ground between stages. In others, the different stages feed

on 2 or 3 different individuals. The host can be identified by the origin of the blood in the tick's stomach, e.g. by PCR analysis. Ticks with a host change are usually better vectors for pathogenic organisms.

Tick species

There are approximately 840 different species of ticks which are classified into 3 families:

- Argasidae: argasids or soft ticks, with a tough, leathery skin and a concealed ventrally projecting capitulum (\pm 170 species). There is no scutum in adult animals. A scutum is a dorsal shield.
- Ixodidae: ixodids or hard ticks have a rigid scutum and a capitulum with mouthparts projecting forwards (\pm 670 species). This capitulum is visible when viewed from dorsal.
- Nuttalliellidae

Overview of tick genera in the three families

- Argasidae : *Argas*, *Ornithodoros*, *Otobius*, *Antricola*, *Nothoaspis*
- Ixodidae : *Amblyomma*, *Aponomma*, *Boophilus*, *Cosmiomma*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Ixodes*, *Margaropus*, *Nosomma*, *Rhipicentor*, *Rhipicephalus*
- Nuttalliellidae : only 1 species, rare

Ticks as vectors

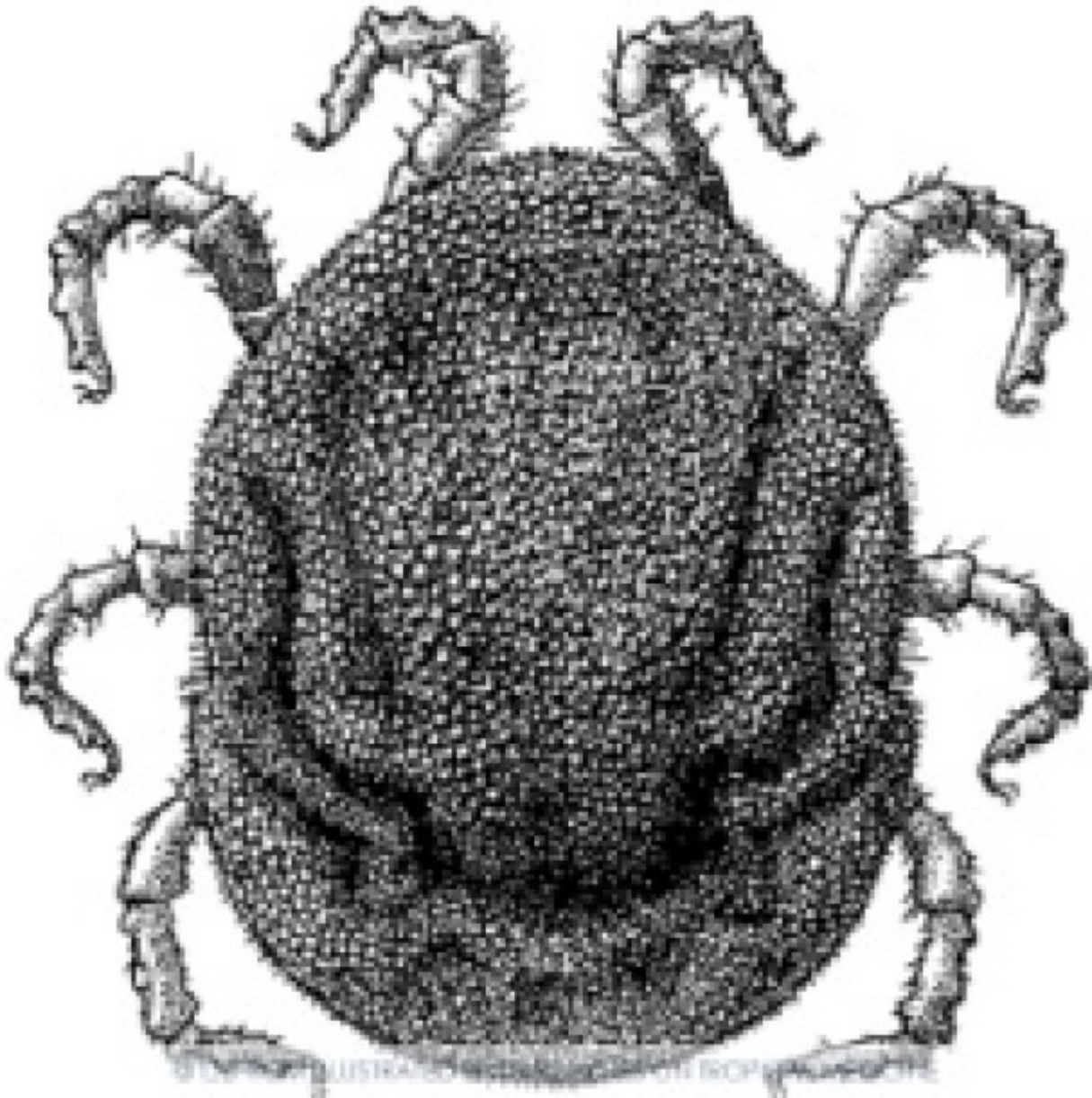
Ticks are always obligate blood suckers, in contrast to mites which occupy much more varied ecological niches. All ticks need blood to complete each stage of their development. The chelicera dilate the skin, so that the hypostome can be inserted. This hypostome is equipped with barbs to keep them anchored in place and thus permit them to suck blood for several days in case of hard ticks. Many ticks cement their mouth parts to the skin for better attachment. This cement needs to be enzymatically broken down when they detach.

Ticks can be important vectors of various infectious organisms for humans (including protista such as babesias; viruses such as Crimean-Congo haemorrhagic fever or tick-borne encephalitis and bacteria such as *Borrelia*, *Rickettsia*, *Ehrlichia/Anaplasma*). Ticks can also transmit diseases in animals: Q fever (*Coxiella burnetii*), theileriosis (*Theileria* sp.), cowdriosis (heartwater, *Cowdria* sp.), dermatophilosis (*Dermatophilus congolensis*, a bacterium), anaplasmosis, babesiosis, sweating sickness (toxin of *H.*

truncatum) and a number of others. The micro-organisms, ticks and their usual natural hosts have developed together over the course of thousands of years with mutual adaptation as a result. As a general rule, the microbes cause little or no damage to the tick and usually persist for the whole of the vector's life. There is often trans-stadial transmission (from larva to nymph to adult) and sometimes transovarian transmission (from tick to eggs, so the following generation is born infected). The micro-organisms usually have little effect on the natural vertebrate hosts. Many of these warm-blooded animals act as a lifelong reservoir and as an amplifier for both pathogens and ticks. Poorly adapted hosts such as humans, often develop diseases following accidental infection with a pathogenic micro-organism. The term "adaptation" can be open to misinterpretation. It is not the case that the long-term persistence of a pathogen in a specific population automatically entails the reduced virulence of this organism.

A significant obstacle for all ticks in obtaining a blood meal is counteracting the haemostatic system of the host, such as thrombin, factor X and platelet aggregation. Ticks have several antihaemostatic agents which are essential for their survival. These products are present in salivary glands, as expected, but also in eggs and haemolymphs. It appears that their function is not only to prevent blood clot formation in the host and the blood meal, but also regulation of haemolymph coagulation in the tick itself. Besides thrombin-inhibitors, inhibitors of tissue factor and factor X or Xa, tick saliva contains a plethora of vasodilators, platelet inhibitors, fibrin (ogen)olytic agents and immunomodulators.

Ticks, Argasidae



Soft tick, *Ornithodoros moubata*. Copyright ITM

Argasids take short (a few minutes) but repeated feeds. After feeding excess water in the blood meal is eliminated partly in the saliva and partly as coxal fluid (e.g. in *Ornithodoros moubata* - syn. *Ornithodoros moubata*). This coxal fluid is secreted by specialised glands between the first and second pairs of legs in the soft tick. *Borrelia duttoni* can be found in this fluid. When this fluid is rubbed into the bite wound an infection can follow. Argasids can cause persistent pruritus at the site of the bite. Some will suck blood from humans if their natural host disappears (e.g. *Argas*

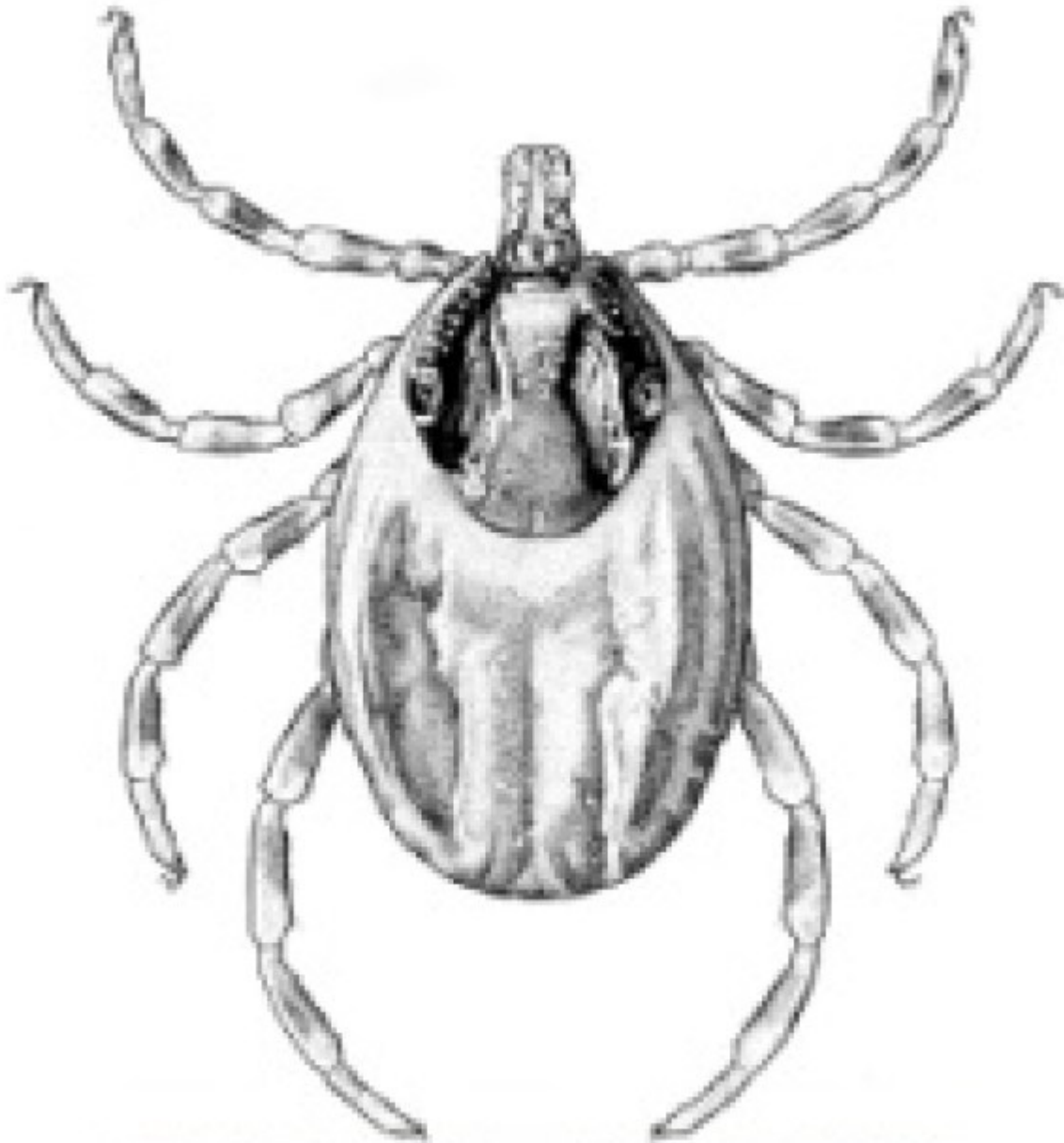
vespertilionis, a bat tick). *Argas reflexus* is a tick which came originally from Middle Eastern countries and has now spread throughout Europe and large parts of Asia via the domesticated pigeon, the host for this animal. Other hosts are hens and ducks. The adults can survive for months to years without a blood meal. Humans can be bitten when visiting an abandoned dovecote. The bite is often painful and the skin will swell and redden.

Ticks, Ixodidae

Hard ticks (Ixodidae) are dispersed world-wide. There are 13 genera, of which *Ixodes*, *Dermacentor*, *Rhipicephalus*, *Haemaphysalis*, *Hyalomma* and *Amblyomma* are the most well-known.



Hard ticks. There are four morphological stages: (left to right) larva, nymph, adult male and female.
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Hard tick: female *Hyalomma aegyptium*. Copyright ITM

The ticks have a hard scutum (dorsal shield) that in the adult male covers the whole back. Males can only suck a limited quantity of blood. The scutum of the female is also hard and cannot distend. It is however smaller so that remarkable distension of the animal's body is possible when it takes a large blood meal. They feed for 6-12 days. It is very important for the tick that during this period it should

not be noticed by the host. Tick bites are painless, since a component of the tick's saliva reduces the sensitivity of the receptors in the host's skin. The males remain on the host for several weeks to months. After the adult female is sated, she falls to the ground in order to lay her eggs. After laying the eggs the female dies. A six-legged larva emerges from the egg and waits for a long time on the ground or on vegetation until a host passes to which it can attach itself. The larva takes one large blood meal over a period of 4 to 6 days.

An eight-legged nymph then develops from the larva, which afterwards develops into an adult animal following a subsequent blood meal (duration 5-8 days). The life cycle of most hard ticks lasts 2 years. The longer the tick remains in place and sucks blood, the larger the quantity of micro-organisms which are transmitted. For example, transmission of Lyme disease is unlikely if the tick is removed rapidly. This is in contrast to the Argasidae, where infections such as relapsing fever can be relatively rapidly transmitted as these animals have a different feeding behaviour. The attachment time needed for transmission of *Borrelia burgdorferi* is much shorter in European ticks than in American ticks.

Tick paralysis

The saliva of some ticks is neurotoxic and "tick paralysis" can occur. This has been described for 60 different tick species in animals, but only a few are important for humans: in the USA and Canada *Dermacentor variabilis* and *D. andersoni* and in Australia *Ixodes holocyclus*, a marsupial tick. Paralysis occurs in animals (dogs, sheep) and humans. Usually the tick needs to have been present for 4 (2-7) days before the symptoms appear. The neurotoxin is still poorly characterised, but it prevents the release of acetylcholine from the pre-synaptic membrane (cf. botulinum toxin). The condition presents as a flaccid, ascending paralysis with areflexia and with bulbar involvement and ataxia, without neck stiffness and without sensory disorders. Unsteady jerky movements of the limbs and breathing difficulties occur. The paralysis is more pronounced in children younger than 10 years, probably because of their smaller body weight. Evolution towards death is possible (respiratory failure). The disorder can resemble poliomyelitis, but motor involvement is symmetrical. Consciousness is clear. It can also resemble Guillain-Barré syndrome, including the EMG findings. On removal of the tick there is a progressive recovery over the course of the following hours to days.

Prevention

Prevention of infections transmitted by ticks includes the avoidance of areas where there are ticks. Argasids are often found in mud huts, campsites or places where pigeons or bats nest. It is best not to sleep on the floor and if possible to avoid such places entirely. The use of concrete or plaster in houses diminishes the population of soft ticks. Hard ticks are found in places where domestic or wild

animals (including birds) congregate, drink, feed or rest. It helps to tuck trousers into socks, wear dark clothing (attracts ticks less) and to wear permethrin or DEET impregnated cloths. A 'skin-check' after a walk through dense vegetation is useful.

Removing ticks

Hard ticks are relatively difficult to remove without damaging them. They have barbs on their hypostome (a section of the mouthparts). Tick larvae are small (<1 mm) and colourless before they suck any blood. They should be removed carefully with tweezers, without squashing them. The tick should be grasped as close as possible to the site of attachment in order to minimise the risk of the mouthparts breaking off and remaining embedded in the skin. The broken-off mouthparts of a tick can cause irritation and local infection. They should be scraped out and the wound disinfected e.g. with alcohol or povidone-iodine. It is sometimes claimed that applying vaseline, butter or fat to the animal (interfering with respiration) causes the tick to react by detaching itself from the skin, after which it can be removed more easily. While this does apply to the removal of fly larvae (myiasis), it is less straightforward in ticks. Burning the animal with a cigarette is not indicated: it can cause burns (particularly in children and pets), the tick might burst, thus spreading infectious material, and finally heat encourages the tick to produce more saliva and regurgitation.

Diseases transmitted by ticks

Soft ticks

Relapsing fever: *Borrelia duttoni* via soft ticks such as *Ornithodoros moubata*

Hard ticks

1. Lyme disease: *Borrelia burgdorferi*
2. Rickettsioses: various types such as Rocky Mountain Spotted Fever, fièvre boutonneuse, Queensland tick typhus, Japanese spotted fever, Israeli tick typhus, Siberian tick typhus, Flinders Island spotted fever, Mongolian spotted fever
3. Ehrlichioses and the related anaplasmosis: monocytic (*E. chaffeensis*) and granulocytic (bacteria related to *E. equi*).
4. Arboviral meningo-encephalitis: TBE (FSME and RSSE), Looping ill, Powassan encephalitis, Colorado Tick Fever (= orbivirus)
5. Arboviral haemorrhagic fever: Crimean-Congo HF, Omsk HF, Kyasanur HF

6. Febrile atypical syndrome: Colorado tick fever, Kemerovo tick fever
7. Babesiosis, e.g. *Babesia divergens*, *B. gibsoni*, *B. microti*
8. Tularaemia, caused by *Francisella tularensis*
9. Tick paralysis: paralysis from neurotoxic substances (e.g. holocycline) in tick saliva

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Myiasis

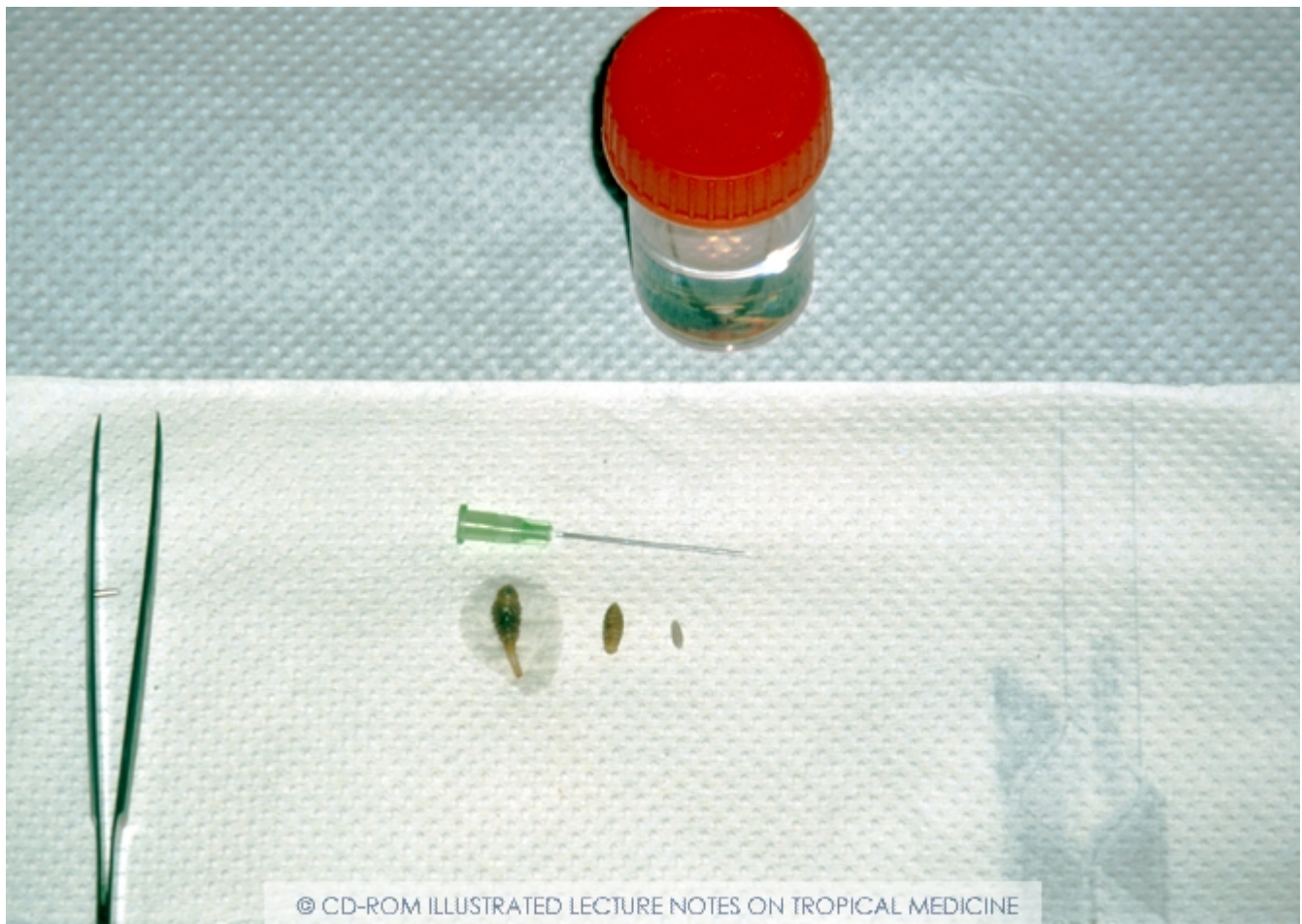
General

Myiasis is the invasion of the body by fly larvae. During this period, the larvae feed on live or dead tissues. Depending on the life cycle of the insect myiasis is obligatory or facultative. In obligatory myiasis, the larvae have to spend part of their life cycle on a living host. Examples are *Cordylobia anthropophaga*, *Dermatobia hominis*, *Cochliomyia hominivorax*, *Chrysomya bezziana* and *Wohlfarthia* sp. In facultative myiasis, the larvae are normally free-living, often on corpses, rotting meat, etc., but are sometimes found on living hosts (e.g. *Calliphora*, *Lucilia*, *Phormia* and *Sarcophaga* sp.) They can infect wounds and superficial ulcers. Clinically a distinction is drawn between cutaneous, urogenital, nasopharyngeal, ophthalmic and intestinal myiasis. Obligatory intestinal myiasis occurs only in animals, not in humans.

Cordylobia anthropophaga



Myiasis, infestation with the larva of a fly (*Cordylobia anthropophaga*). Copyright ITM



Myiasis, *Dermatobia hominis* and *Cordylobia anthropophaga*. Copyright ITM

Cordylobia anthropophaga (tumbu fly, ver de Cayor) is a thick brown fly limited to tropical Africa. The larvae are obligate parasites, among others of dogs and humans. The female lays her 100-300 eggs on shaded, polluted ground or on dirty or inadequately washed sheets or clothes with some traces of sweat or urine still on it, laid out on the ground in the shade to dry. The females never lay their eggs on clothing that has been hung up in direct sunlight and also never directly on the skin. The larvae that emerge from the eggs penetrate the epidermis as far as the subcutaneous fatty tissue and develop there for 8 to 12 days. They then crawl out of the skin and fall to the ground where they undergo pupation in 24 hours. The pupae develop into adult flies in 10 to 20 days. The larvae rapidly penetrate the skin without causing any pain. In the first few days, an itchy, painful papule appears which develops over the course of a week into a painful furuncle in the centre of which two black dots (respiratory canals) are visible. The lesions may be few or numerous. The larvae can be pressed out of the skin if their respiration is prevented by coating the lesion with vaseline. One way to avoid

infection is to iron bed linen and clothes on both sides.

Dermatobia hominis

Dermatobia hominis (ver macaque) occurs in scrubland and woody lowland regions of Latin America. This large (15 mm) blue-grey fly has a remarkable life cycle. During their short life (8-9 days) adult females seize various bloodsucking insects. They then attach 6-30 eggs to the body of these arthropods, which include *Psorophora* mosquitoes and stable flies (*Stomoxys calcitrans*). Cattle flies (*Haematobia irritans* and *H. exigua*) can also act as transport hosts. In some cattle breeding districts they constitute a real plague. The larva of *Dermatobia hominis* develops in the egg. When the transport insect sucks blood the larva feels the higher temperature and breaks out of the egg and drops onto the skin or fur. Subsequently the *Dermatobia* larva penetrates the skin relatively rapidly. The larvae cause rather large cutaneous lesions, often painful and pruritic, few in number and frequently solitary and localised on the head. Development is slow, up to 12 weeks (up to 18 weeks has been reported). Fluid is formed constantly, consisting of the excreta of the larvae, but there is rarely superinfection. If this occurs, cellulitis and lymphangitis can follow. Frequently, the larvae have to be removed surgically (the final size of the larvae is 18-25 mm). A non-invasive technique of removing larvae is based on topical application of Vaseline to cut off their oxygen supply but this does not work very well. Fresh bacon can also be tried, the white part of the raw bacon is laid on the wound for some hours until the larva has attached itself. The bacon should then be lifted up and the larva can be grasped and removed with a rapid movement.



Myiasis; *Dermatobia hominis*; infestation with fly larva; photo Dr Van den Enden, copyright ITM

Prevention of *Dermatobia hominis* infections is difficult. The transport host *Haematobia irritans* ("horn fly") principally bites cattle and can be successfully combated by "ear tags" containing a PVC matrix with pyrethroids. They can also bite humans. When these insects form a local plague, they can be controlled in a "low-tech" fashion since *Haematobia irritans* and *H. exigua* obligatorily lay their eggs on fresh cow dung. When this is broken up mechanically, the larvae die. A shepherd with a rake can diminish a local plague and limit the exposure of humans and animals.

Screw worms

Cochliomyia hominivorax ("New World screw worm"; syn. *Callitroga hominivorax*) is a fly that occurs in Latin America and the Caribbean. It belongs to the Calliphoridae ("blow flies"). It was first described in 1858 by Dr Coquerel, a French army doctor in Cayenne, French Guyana. Many of the prisoners in the penal colony of Devil's Island had infections in the nose and sinuses. The insect lays its eggs on all types of wounds. The larvae bore deep in the tissues with serious consequences, such as mutilation or even death. Although the species name translates as "man eater", the insect preferentially plagues cattle. The name "screw worm" refers to the somewhat screw-like appearance of the larvae. They

have mouth hooks in order to attach themselves firmly. Treatment consists of the mechanical removal of the intact larvae, standard wound care and tetanus prophylaxis. Antibiotics are usually necessary to combat superinfection.

Chrysomya bezziana ("Old World screw worm") strongly resembles *Cochliomyia hominivorax*, but does not lay its eggs on wounds. When larvae invade natural openings (vagina, nose, eyes, mouth), they can cause very painful and serious lesions. The larvae complete their development in humans in 5-6 days, after which they crawl out of the tissues and fall to the ground to pupate. *Chrysomya megalocephala* is a facultative parasite of humans.



Myiasis. Adult *Chrysomya bezziana*, dorsal view. Copyright ITM

Tabanids

Stinging flies that belong to the tabanids (*Haematopota*, *Chrysops*, *Tabanus*) can be mechanical vectors for anthrax and tularaemia (“rabbit fever”). This last infectious disease is caused by *Francisella tularensis*.

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Bed bugs



Cimex lectularius, bed bug. These insects are not known to transmit human pathogens. Photo copyright ITM

There are two main species of bed bugs: ***Cimex lectularius*** (the common bed bug which occurs world-wide) and ***Cimex hemipterus*** (the tropical bed bug). In West Africa, *Leptocimex bouetti* attacks man. Bed bugs are insects (4-7 mm) with rudimentary, non-functional wings. This limits their capacity for dispersion. They are not vectors of pathogenic organisms, but are primarily a nuisance because of their behaviour. They suck blood for a short time during the night or at dawn. During the

day the adult insects hide in cracks and crevices. Often dirty brown spots caused by their faeces are found on sheets, walls or floors. Sometimes clusters of hundreds of 1 mm large whitish-yellow eggs can be seen on walls, under wallpaper, etc. After a bite a severe pruritic skin reaction can occur.

Spraying insecticides helps control these animals. The problem of increasing insecticide resistance among bedbugs is getting worse. DEET has a repellent effect, but makes it that blood meals are often interrupted, therefore the insect will bite several times in order to get the same amount of blood. This means that this repellent is less than ideal. Aggressive and total extermination on an infestation is the only solution for infested premises. If this is unfeasible an alternative would be to take oral ivermectin and let the bugs bite the next night. Ivermectin is a neurotoxin for these insects and will kill them.

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Beetles

General

Although beetles have the greatest wealth of species of all insects, only a few are directly harmful to human health. A few beetles, chiefly belonging to the Scarabaeidae and Tenebrionidae, can be intermediate hosts for worms, such as the tapeworm *Hymenolepis diminuta* (the cause of non-specific abdominal discomfort).

Blister beetles

Blister beetles are insects that cause skin lesions by direct contact. They are found on various continents. They contain highly poisonous substances such as cantharidin or pederin. Cantharidin is found in the haemolymph of the beetle and is released when the insect is crushed. A number of insects secrete the caustic fluid via their leg joints when they are disturbed ("reflex bleeding"). In *Lytta vesicatoria* cantharidin is also found in the wing sheath.



Paederus sp. blister beetle. Contact with the animals can result in severe dermatitis or eye inflammation. The insects contain paederin, a blistering agent. Copyright ITM

Blister beetles toxins



Dermatitis resulting from contact with blister beetles (*Paederus* sp). Copyright ITM, Dr Van den Enden



Dermatitis secondary to contact with a blister beetle, *Paederus* sp. (fam. Staphylinidae). Contact with the eyes leads to the so-called "Nairobi eye". Copyright ITM

Pederin

Pederin is the active vesicant of the short-winged beetle *Paederus fuscipes* and related species. It is a complex non-protein molecule. Pederin is highly toxic, more potent than cobra venom. It inhibits protein synthesis and prevents cell division.

Cantharidin

Cantharidin binds chemically to phosphatases 1 and 2A. The toxin is very stable. Dead beetles are still dangerous. Consequently control by means of insecticides does not remove the danger. The toxin

protects the beetles from predators and is found in the haemolymph and gonads.

Cantharidin systemic effects

Sometimes cantharidin is swallowed. The toxin is readily absorbed from the intestine and excreted in the urine. If cantharidin is swallowed to arouse sexual appetite, in an attempted suicide, by accident, with criminal intent or to induce abortion, several symptoms may occur depending on the dose. The initial discomfort begins within 30 minutes. Dysphagia as a result of mucositis with irritation of oral, oesophageal and gastric mucosa is followed by abdominal pain, nausea and vomiting, possibly with blood. Oedema, bleeding and necrosis of the mucosa occur at an early stage. There is intense congestion of the genito-urinary tract, with bleeding in the renal pyelum, ureters and bladder. Bleeding can also occur in the ovaries. Sometimes there is internal bleeding and bruising. Priapism occurs, which was the origin of the use of the substance as an aphrodisiac (Gr. Aphrodite = goddess of love). Diarrhoea occurs, accompanied by leukocytosis, haematuria, renal tubular necrosis, uraemia, shock and coma. Approximately 30-60 mg is sufficient to kill an adult person.

Clinical aspects

On skin contact with cantharidin-containing blister beetles, local tissue irritation occurs after a few hours. In intra-epidermal blister formation, redness, oedema and vesicles can appear on the skin. Sometimes there are “kissing lesions” on the elbow or in the hollow of the knee. In contrast, the effect of pederin is not immediately noticeable and only becomes apparent after 1 to 2 days. The erythema is much more severe and can persist for months. On contact with the conjunctiva and/or cornea, *Paederus* sp. cause “Nairobi eye”. This is associated with extensive painful peri-orbital swelling and purulent conjunctivitis. Corneal erosions and blindness can follow.

Treatment

For external lesions, the skin should be rinsed copiously as rapidly as possible. After disinfection, silver sulphadiazine cream should be applied. Subsequent care is the same as for a burn. Skin lesions caused by cantharidin practically always heal without leaving scars. An eye that is affected should be rinsed copiously. Afterwards an antibiotic- and steroid-containing eye ointment should be applied (cfr. eye lesions caused by spitting cobras).

There is no specific antidote. Steroids are not effective in controlling the ulcers in the gastro-intestinal tract. Fluid, calcium supplements, analgesics and broad spectrum antibiotics should be given. Gastric

lavage should be carried out and activated charcoal administered. Cantharidin is to a large extent bound to albumin and is not removed by haemodialysis via a charcoal column. Physiological fluid should be administered IV. A blood transfusion might be necessary. Maximum diuresis must be obtained with IV fluid, mannitol and diuretics. No fat should be given orally because it increases the absorption of the toxin.

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Leeches

General

The phylum Annelida is subdivided into three classes: Polychaeta ("bristle worms", principally marine animals), Oligochaeta (e.g. earthworms) and Hirudinida ("leeches"). Among the latter there is a subclass of Hirudinea (the true leeches) with 12 families. They include terrestrial, freshwater and saltwater species. There are approximately 650 species, but not all of these constitute a problem for humans. Terrestrial (semiterrestrial is a better term) and amphibious species are common in Southeast Asia, the islands in the Pacific Ocean, India and South America. Aquatic species occur worldwide. They are seldom found in low-calcium water. They are good swimmers. Usually victims are people visiting marshy areas or walking in or near slow-moving small brooks or streams.

Leeches bites

On biting leeches introduce vasodilators and hirudin, a very powerful anticoagulant into the skin. The bite causes prolonged painless local bleeding. Once sated after sucking two to five times their own weight of blood they let go and drop to the ground. They feed infrequently. After a large blood meal, the animal can go for over 6 months without feeding. The blood is then digested in the gut over a 100-day period, during which water is extracted and excreted through several pairs of ventrally located nephridia.

Clinical aspects

Leeches can attach to the skin. With the anticoagulant, they also inject a local anaesthetic, so pain is absent. Prolonged wound bleeding can result. Removal of a leech can be facilitated by applying a little alcohol or vinegar. If necessary a burning cigarette may be held near the parasite. No attempt should be made to remove the animals rapidly because the jaws can remain behind. After wound cleaning, local pressure should be applied to stem the bleeding. The bleeding tendency can persist for many

hours, sometimes even up to 2 days. This illustrates the power of the animal's anticoagulants. Aquatic species can attach to the conjunctiva, nose, nasopharynx, vagina and urethra. When they attach themselves to the epiglottis, trachea or bronchi, serious complications are likely. Internal bleeding, haemoptysis, chronic headache, dysphagia and hoarseness occur. The leeches can be loosened by local application of cocaine or lidocaine. They are removed carefully with a forceps, using a laryngoscope or endoscope. As a rule the leech itself does not transmit any pathogens, although some recent observations from Laos suggest that it might transmit *O. tsutsugamushi*. Wounds can become secondarily infected. *Aeromonas* infections can occur but is rare. Following repeated bites, hypersensitivity can occur. For prevention, protective clothing should be worn. A topical repellent such as dimethyl phthalate or dibutyl phthalate, may be applied.

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