11 Arthropods

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Parasitic arthropods are ectoparasites that have a temporary or permanent association with their hosts. Their considerable medical significance is due to their capability to cause nuisance or skin diseases in humans and to act

Table 11.1 Classification of Arthropods Mentioned in the Text

Subphylum ■ Class	Order* ■ Suborder	Genus
Amandibulata		
■ **Arachnida**	Metastigmata[1] (ticks)	Family Ixodidae: *Ixodes, Dermacentor, Rhipicephalus, Haemaphysalis etc.*; family Argasidae: *Argas, Ornithodoros*
	Mesostigmata[2] (mites)	*Dermanyssus, Ornithonyssus*
	Prostigmata[3] (mites)	*Cheyletiella, Neotrombicula*
	Astigmata[4] (mites)	*Sarcoptes, Notoedres, Psoroptes, Tyrophagus, Tyroglyphus, Glyciphagus, Dermatophagoides*
Madibulata		
■ **Insecta**	Anoplura (lice)	*Pediculus, Phthirus*
	Heteroptera (bugs)	*Cimex, Oeciacus, Triatoma, Rhodnius, Panstrongylus*
	Diptera	
	■ Nematocera (mosquitoes, black flies etc.)	*Anopheles, Culex, Aedes, Simulium, Phlebotomus, Lutzomyia*
	■ Brachycera (flies)	*Musca, Glossina, Calliphora, Cochliomyia, Cordylobia, Lucilia, Sarcophaga, Wohlfahrtia, Gasterophilus, Hypoderma, Cuterebra*
	Siphonaptera (fleas)	*Pulex, Ctenocephalides, Ceratophyllus, Archaeopsylla, Xenopsylla, Tunga, etc.*

*Syn. [1]Ixodida, [2]Gamasida, [3]Trombidiformes, [4] Sarcoptiformes.

as vectors of viruses, bacteria, protozoa, or helminths. Some species or stages of arthropods are capable of penetrating to deeper skin layers or into body openings or wounds, where their effect is similar to that of endoparasites. Only a small selection of medically important arthropods will be described in the following chapter (see Table 11.**1**), in particular those that are of significance in central Europe. The reader is referred to the literature for more detailed information (see p. 660).

Arachnida

Ticks (Ixodida)

General. The order Ixodida includes two important families, the Argasidae (soft ticks) and Ixodidae (hard ticks). The latter is the most significant group worldwide. We will only be considering the Ixodidae here.

Approximately 20 hard tick species are indigenous to western and central Europe, belonging to the genera *Ixodes*, *Rhipicephalus*, *Dermacentor*, and *Haemaphysalis*. The most important species is *Ixodes ricinus* that accounts for about 90 % of the tick fauna in this region. For this reason, human tick bites in central Europe are in most cases caused by *I. ricinus* and only occasionally by other tick species.

Ixodes ricinus

Vector of the causative agents of Lyme borreliosis and tickborne encephalitis

■ *Ixodes ricinus*, (common sheep tick, castor bean tick) is the most frequent hard tick species in central Europe. The medical significance of this species is due to its role as vector of the causative agents of Lyme borreliosis, tickborne encephalitis (European tickborne encephalitis, "early summer meningoencephalitis," ESME), and other pathogens. Ticks that have attached to the skin should be mechanically removed as soon as possible to reduce the risk of infection. ■

Morphology. *Male*: about 2–3 mm long with a highly chitinized scutum covering the entire dorsal surface. *Female*: 3–4 mm, up to 12 mm when fully engorged after a blood meal; the scutum covers only the anterior portion of the body (Fig. 11.**1a**). Adults and nymphs (the latter about 1 mm long) have four pairs of legs, the smaller larvae (about 0.5 mm long) only three pairs. Ticks possess characteristic piercing mouthparts.

Arthropod Parasites of Man

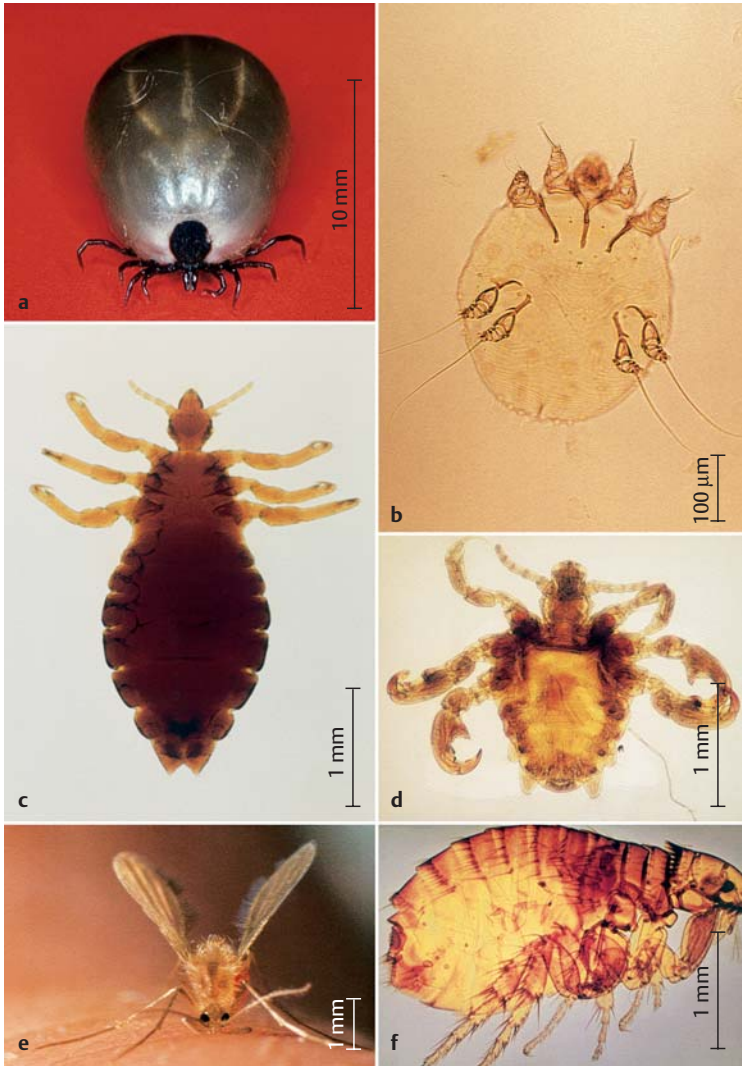


Fig. 11.1 **a** *Ixodes ricinus*, female engorged with blood; **b** *Sarcoptes scabiei*, female; **c** body louse; **d** crab louse; **e** sandfly (*Phlebotomus papatasi*) feeding on human skin; **f** dog flea (*Ctenocephalides canis*). (Image e: H. M. Seitz, Institut für Medizinische Parasitologie, Bonn.)

Biology. The various stages of *I. ricinus* are dependent on blood meals from vertebrates throughout their developmental cycle. Having selected a suitable location on a host, a female tick inserts her piercing mouthparts into the skin within about 10 minutes. Using clawlike organs at the tip of stylettelike mouthparts, the chelicerae, the tick cuts a wound into which the unpaired, barbed, pinecone-shaped hypostome is then inserted to anchor the parasite in the skin. While sucking blood, ticks secrete large amounts of saliva, containing cytolytic, anticoagulative, and other types of substances. They ingest blood, tissue fluid and digested tissue components. The weight of the female increases considerably during a blood meal. When completely engorged, the tick resembles a ricinus seed. The epidemiologically important factor is the possible ingestion of pathogens with the blood meal, which can, at a following blood meal in the tick's next developmental stage, be inoculated into another vertebrate host (horizontal transmission). Female ticks even transmit certain pathogens by the transovarial route to the next generation of ticks (vertical transmission).

Table 11.**2** summarizes the life cycle of *I. ricinus*. The overall development period may be interrupted by periods of inactivity and starvation (maximum starvation capacity 13–37 months, depending on the stage) and can therefore take from one to three years.

Epidemiology. *I. ricinus* occurs widely in Europe, both in lowland and mountainous regions up to 800–1000 m above sea level, occasionally even higher. The habitats preferred by this species include coniferous, deciduous, and mixed forests with plentiful underbrush and a dense green belt. The different

Table 11.**2** Life Cycle of *Ixodes ricinus*

Developmental stages:	**Egg →**	**Larva →**	**Nymph →**	**Imago**
Host groups commonly used for blood feeding:	–	Rodents, birds, (humans)[1]	Birds, mammals[2], humans	Domestic and wild ruminants, dogs, cats, horses, and other animal species[2], humans
Duration of bloodsucking, in days:	–	2–6	3–7	5–14
Tick habitat when not attached to a host:	Humid soil, low vegetation, areas of woodland with underbush, meadows with high grass, gardens etc.			

[1] Occasionally. [2] Many different host species; in Europe about 35.

stages of ticks inhabit grass, ferns, and branches in this low vegetation either quite close to the ground (mainly larvae and nymphs) or somewhat higher (up to about 80–100 cm, mainly adults) in questing for suitable hosts. When hosts approach, the ticks either let themselves drop onto them or cling to the skin on contact. *I. ricinus* becomes active at 7–10 °C. Maximum tick activity is registered in the periods May-June and August-October.

The great epidemiological significance of *I. ricinus* in central Europe is predominantly due to its function as vector of the causative agents of Lyme borreliosis (*Borrelia* spp., p. 324f.) and the European tickborne encephalitis (TBE) (virus of TBE, p. 443f.). In northern and eastern Europe the TBE virus is transmitted by *Ixodes persulcatus*; *Ixodes scapularis* (syn. *I. dammini*) is the vector of *Borrelia burgdorferi* in the USA.

Diagnosis. Identification of *I. ricinus* is either done macroscopically or with the help of a magnifying glass. Differential species identification requires the skills of a specialist. Skin reactions, in particular the erythema chronicum migrans resulting from a borreliosis infection, often provide indirect evidence of an earlier tick bite.

Tick bite prevention. Tick habitats with dense undergrowth, ferns, and high grasses should be avoided as far as possible. If this is unavoidable, proper clothing must be worn: shoes, long socks, long trousers (tuck legs of trousers into socks), long sleeves that fit closely around the wrists. Additional protection is provided by spraying the clothes with acaricides, especially pyrethroids, which have a certain repellent effect (e.g., flumethrin). The effect of repellents applied to the skin (see malaria) is in most cases insufficient to protect against ticks.

After staying in a tick habitat persons should search their entire body for ticks and remove any found attached to the skin as quickly as possible by mechanical means (do not apply oil or other substances to attached ticks!). Any bites should be watched during the following four weeks for signs of reddening (erythema), swelling, and inflammation. A "migrating," i.e., spreading rash (erythema migrans) is indicative for a *Borrelia* infection. On the other hand, this sign is not observed in all infected persons.

Mites

Sarcoptes scabiei
Causative agent of scabies ("the itch," "sarcoptic itch")

11

■ Infestation with *Sarcoptes scabiei* var. *hominis* causes human scabies, a condition characterized by pronounced pruritus, epidermal mite burrows, nodules, and pustules. Transmission is person to person. Various mite species that parasitize animals may also infest the human skin without reproducing, causing the symptoms of "pseudoscabies." ■

Occurrence. Scabies caused by *Sarcoptes scabiei* var. *hominis* does not occur frequently in Europe, although occasional outbreaks are seen in school classes, families, senior citizens' homes, and other groups.

Morphology and biology. *Sarcoptes scabiei*: mites about 0.2–0.5 mm long with ovoid bodies. The adults and nymphs have four pairs of legs (Fig. 11.**1b**), the larva has three pairs of legs. Following transmission to a human host the female mites penetrate into the epidermis and begin to tunnel. The resulting winding burrows are usually 4–5 mm and sometimes as long as 10 mm. Oviposition begins after only a few hours. Six-legged larvae hatch from the eggs after a few days. In further course of development involving moltings, the larvae transform into protonymphs (nymph I), then deutonymphs (nymph II), and finally adult males and females. The entire life cycle takes two to three weeks. The lifespan of the female mites is four to six weeks.

Epidemiology. Transmission is by close contact (sexual partners, family members, school children, healthcare staff) from person to person, whereby female mites translocate to the skin of a new host. Indirect transmission on clothes (underclothes), bed linens, etc. is not a primary route, but should be considered as a factor in control measures. Without a host, mites usually die off within a few days. Mite infections can also be acquired from animals to which humans have close skin contact.

Clinical manifestations. An early sign of an initial infestation with *Sarcoptes* mites is the **primary efflorescence** with mite tunnels up to 2–4 mm and sometimes 10 mm long—threadlike, irregularly winding burrows reminiscent of pencil markings. The female mite is found at the end of the burrow in a small swelling.

Following an inapparent period of about four to five weeks, during which time a hypersensitivity response to mite antigens develops, the **scabies exanthema** manifests in the form of local or generalized **pruritus**, which is particularly bothersome in the evening when body heat is retained under the bedcovers. The evolving skin lesions are papulous or papulovesicular exanthema and reactions due to scratching. In adults, these lesions are seen mainly in the interdigital spaces and on the sides of the fingers, on the wrists and ankles and in the genital region. Children also occasionally show facial lesions.

A special form of the infestation may develop in immunocompromised patients: **scabies crustosa** (formerly scabies norvegica). This type is characterized by pronounced crusted, flaking lesions, particularly in the head and neck region. Massive reproduction of the mites makes this condition highly contagious.

Diagnosis and control. Case history and clinical manifestations provide important diagnostic hints that require etiological confirmation by identification of the parasites (Fig. 11.**1b**). A papule is removed by tangential scalpel excision, whereupon the specimen is macerated in 10% potassium hydroxide (KOH), and then examined for mites under a microscope. Mites can also be isolated from skin tunnels after scarification with a needle or by pressing adhesive tape onto the skin. Therapy requires topical application of γ-hexachlorocyclohexane (lindane), permethrin or crotamiton in strict accordance with manufacturer's instructions. A recent development is peroral therapy with ivermectin. Underclothing and bed linens must be washed at a minimum temperature of 50 °C.

Other Mites

The preferred hosts of mites of the orders Astigmata (e.g., *Sarcoptes scabiei* var. *suis, S. scabiei* var. *canis, Notoedres cati, Psoroptes ovis*), *Prostigmata* (e.g., *Cheyletiella, Neotrombicula*), or *Mesostigmata* (e.g., *Dermanyssus, Ornithonyssus*) are vertebrate animals (usually domestic animals), with occasional human infestations. On human hosts the mites remain temporarily on or in the skin without reproducing, causing a variety of skin lesions involving pruritus, most of which abate spontaneously if reinfestation can be prevented. It is important to prevent such infestations by treating of mite-infested animals and—if needed—by decontaminating their surroundings.

Some groups of nonparasitic ("free-living") mites are known to induce allergies. The so-called forage or domestic mites (e.g., *Glyciphagus, Tyrophagus, Tyroglyphus*) develop mainly in vegetable substrates (grain, flour, etc.) and can cause rhinopathies, bronchial asthma, and dermal eczemas ("baker's itch," "grocer's itch") due to repeated skin contacts with or inhalation of dust containing mites. Widespread and frequent in human dwellings are several species of house-dust mites (above all *Dermatophagoides pteronyssinus*) that are an important cause of "house-dust allergy" (dermatitis, inhalation allergy).

Insects

Lice (Anoplura)

Causative agents of pediculosis and phthiriosis (louse infestations)

■ Head lice and crab lice occur more frequently in central Europe and elsewhere than is generally assumed and must therefore always be taken into consideration when diagnosing skin diseases. ■

Parasite species. Two species of lice infest humans, one of which is divided into two subspecies (Table 11.**3**).

General morphology and biology. Lice are dorsoventrally flattened insects, about 1.5–4 mm in length, wingless, with reduced eyes, short (five-segmented) antennae, piercing and sucking mouthparts, and strong claws designed to cling to hairs (Fig. 11.**1c**).

Lice develop from eggs (called nits) glued to hairs. The hatched louse grows and molts through three larval stages to become an adult. Lice remain on a host permanently; both males and females are hematophagous and require frequent blood meals. Lice are highly host-specific, so that animals cannot be a source of infestation for humans.

Medical significance. Among the various species of lice only the body louse is a vector of human diseases. It transmits typhus fever (caused by *Rickettsia prowazekii*), relapsing fever (caused by *Borrelia recurrentis*), and trench fever (caused by *Bartonella quintana*). In central Europe, the medical importance of lice is not due to their vector function, but rather to the direct damage caused by their bites (see below).

Pediculus humanus capitis (Head Louse)

Morphology and biology. Oval body, length 2.2–4.0 mm, morphology very similar to the body louse. Nits are 0.5–0.8 mm long. Localization is mainly in the **hair on the head,** occasionally also on other hairy areas of the head or upper body. The nits are glued to the base of the hair near the skin. Duration of development from nit to adult is 17 days. The lifespan of adults on human host about one month, survival off host at room temperature is for up to one week.

Occurrence and epidemiology. Occurs worldwide; in central Europe it is not frequent, but epidemic-like outbreaks of head louse infestation are observed regularly, especially in schools and kindergartens, homes, groups of neglected

Table 11.**3** Lice that Infest Humans

Species	Main localization of lice and sites of oviposition
Pediculus humanus capitis (head louse)	Hair on the head, rarely on beard hairs or hairy sites on upper body
Pediculus humanus corporis (body louse)	Stitching, seams, and folds in clothes, especially where it is in direct contact with the body
Phthirus pubis (crab louse)	Hair of pubic area, more rarely in the abdominal and axillary regions, beard, eyebrows, and eyelashes

persons, etc. Children and women are most frequently infested. About 60% of persons with lice show low levels of infestation with <10 adult lice, the others higher levels (up to >1000 lice). According to official statistics, head louse infestation in the UK increased between 1971 and 1991 about sevenfold; in 1997, about 18.7% of the schoolchildren in Bristol were infested with lice.

Transmission is in most cases by personal contact (mother-child contacts, children playing, etc.), but can also be mediated by such objects as combs, caps, pillows, head supports, stuffed animals, etc.

Clinical manifestations

- Pruritus and excoriations in the scalp area, nits on hairs, especially in the retroauricular area.
- In some cases scalp dermatitis, especially at the nuchal hair line: small papules, moist exanthema, and crusting.
- Occasionally also generalized dermatitis on other parts of the body caused by allergic reactions to louse antigens.
- Both objective and subjective symptoms may be lacking in up to 20% of cases.

Diagnosis. Determination of symptoms and detection (direct or with magnifier) of lice and/or nits, especially around the temples, ears, and neck.

It is important to clarify the epidemiological background regarding all possible sources of infestation (e.g., in schools). Some countries have introduced regulations on control of outbreaks of louse infestation in schools and other community institutions.

Therapy. In group outbreaks, all contact persons must be treated concurrently, e.g., entire school classes and the families of infested children. A variety of different insecticides are available for therapy, for instance pyrethrum, permethrin, malathion, and γ-hexachlorocyclohexane (γ-HCH, lindane). (Important: lice may show resistance to certain insecticides!) Follow the preparation application instructions and repeat application after seven to 10 days. Rinsing the hair with 5% vinegar in water followed by mechanical removal of the nits with a "louse comb" is a supportive measure.

Control. Clothing, pillows, etc. that have been in contact with lice must be decontaminated: wash laundry at 60 °C; keep clothes and other objects in plastic bags sealed with adhesive tape for four weeks or deep-freeze the bags for one day at –10 to –15 °C. Clean upholstered furniture, mattresses, etc. thoroughly with a vacuum cleaner and decontaminate as necessary (consult an expert for pest control).

Pediculus humanus corporis (Body Louse)

Occurrence, morphology, and biology. Very rare in central Europe. Oval body, length: 2.7–4.7 mm. Very difficult to distinguish from head louse (Fig. 11.**1c**). Localization mainly in clothing, where nits are deposited on fibers. These lice contact to the host only for blood meals. Duration of life cycle about three weeks, lifespan on host usually four to five weeks, rarely as long as two months; can survive without a host at 10–20 °C for about one week and at 0–10 °C for approximately 10 days.

Clinical manifestations, diagnosis, and control. Bite reactions on the body, especially around the underwear, are indicative of body louse infestation. To confirm diagnosis inspect clothing for nits and lice. Control: see head louse p. 614.

Phthirus pubis (Crab or Pubic Louse)

Occurrence, morphology, and biology. The crab louse occurs with some regularity in central Europe. Infestations are more frequent in adults than in children and in men more frequently than in women. This louse species can be readily differentiated from the head or body louse: small, length 1.3–1.6 mm, with trapezoid or crablike body form (Fig. 11.**1d**). The parasites are most often found on hair of the **pubic and perianal region**, more rarely on hairy areas of the abdominal region, hairs around the nipples, beard hairs, eyelashes, and eyebrows. The life cycle takes three to four weeks. Deprived of a host, crab lice die at room temperature within two days.

Epidemiology. Transmission of crab lice is almost solely by way of close body contact (sexual intercourse in adults or parent-child contact). Indirect transmission on commonly used beds, clothes, etc. is possible, but is not a major factor.

Clinical manifestations

- Pruritus and scratches in the genital area and other infestation sites (see above).
- In some patients typical slate-blue spots, a few mm to 1 cm in size (maculae coeruleae, macula = spot, coeruleus = blue, blackish).

Diagnosis, therapy, control. Detection of lice and nits in the pubic area and other possible localizations by means of inspection (magnifying glass!). Treatment with lindane, malathion, or other substances (see also head louse). It is important to identify contact persons and have them treated as necessary.

Bugs (Heteroptera)

Cimex lectularius (family *Cimicidae*), the bedbug, occurs worldwide. Now rare in central Europe, it is therefore often not considered when diagnosing skin lesions. Bedbugs live on human blood. Especially in repeated infestations, their bites induce hemorrhagic or urticarial-papulous reactions, often visible as lesions arranged in groups or rows. The bugs are about 3–4 mm long, with dorsoventrally flattened bodies, greatly reduced wings and a bloodsucking proboscis that can be folded back ventrally. Development from the egg through five larval stages to the adults takes about one and a half months under suitable conditions, but can be extended to as long as one year. Bedbugs require several blood meals during development and egg production. Their ability to starve for as long as a year means they can persist for long periods in rooms, hiding by day (under mattresses, behind furniture, in cracks in the walls, etc.) and emerging at night questing for a blood meal. Diagnosis: skin lesions and detection of bugs in the vicinity. Therapy: symptomatic. Control by means of room decontamination. Other bugs do at times bite humans, e.g., the swallow bug (*Oeciacus hirundinis*), which sometimes leave birds' nests to invade human dwellings. Bugs of the family *Reduviidae* (genera *Triatoma*, *Rhodnius*, etc.) transmit Chagas disease (see p. 491).

Mosquitoes and Flies (Diptera: Nematocera and Brachycera)

■ Many dipteran species act as vectors of pathogens. Their bites also cause local reactions, and fly maggots may even penetrate into and colonize the skin, wounds, or natural orifices, thereby causing considerable tissue damage. ■

Role as vectors. Many species of Nematocera are significant vectors of pathogens, e.g., *Anopheles* mosquitoes transmitting the malaria parasites, *Aedes aegypti* which is the principal vector of the Dengue virus, or *Phlebotomus* sandflies (Fig. 11.**1e**) transmitting the causative agents of leishmanioses (see Chapter 9). Nematocera also transmit many other pathogens—not only in the tropics, but in central Europe as well.

The same applies to numerous fly species e.g., *Glossina* flies, the vectors of the sleeping sickness agents. Flies can also disseminate various pathogens mechanically (e.g., bacteria, parasites).

Bite reactions. The bites of Nematocera and flies can cause more or less pronounced primary dermal reactions (e.g., mosquitoes of the genus *Aedes* or blackflies of the family *Simuliidae*) or allergic skin reactions.

Table 11.**4** Important Forms of Myiasis in Humans

Form of myiasis	Type of infestation	Infesting flies (genera, selection)
Cutaneous myiasis		
■ Furuncular myiasis	Larvae form focal skin swellings with central small hole	*Dermatobia, Cordylobia, Cuterebra*
■ "Creeping eruption"	Larvae tunnel in epidermis and induce focal skin swellings	*Hypoderma, Gasterophilus*
■ Wound myiasis	Deposition of eggs or larvae in wounds	*Sarcophaga, Calliphora, Musca, Wohlfahrtia, Lucilia, Cochliomyia*
Other forms		
■ Nasopharyngeal, ocular, auricular, and urogenital myiasis	Deposition of eggs or larvae in nasal orifices, eyes, auricular orifices, vulva, etc.	*Sarcophaga, Calliphora, Musca, Wohlfahrtia, Lucilia*

Myiasis. Larvae (maggots) of various fly species can penetrate and colonize the skin, skin lesions, and body orifices, thereby causing the type of tissue damage known as myiasis. There are various forms of myiasis, the most important of which are summarized in Table 11.**4**. Cases of imported myiasis and autochthonous wound myiasis have increased in central Europe in recent years. Diagnosis: inspection and identification of the larvae. Therapy: mechanical removal of the parasites, control of secondary infections, if required oral therapy with ivermectin (extralabel drug use).

The maggots of certain fly species (*Lucilia* spp.) raised under sterile conditions are sometimes used for treating patients with necrotizing or nonhealing dermal lesions. In many cases, the maggots are able to clean such wounds in short order.

Fleas (Siphonatera)

Causative agents of flea infestation

■ The "human flea" (*Pulex irritans*) is rare, but humans are frequently attacked by flea species that normally parasitize animal species. Bite reactions can be identified on the human skin, but the parasites must be found and controlled on animals or in their environment. Travelers to tropical areas may become infested with sand fleas (*Tunga penetrans*). ■

Species and occurrence. At least 2500 species of fleas have been described worldwide. About 100 of these occur in central Europe, of which the medically important species belong mainly to the families Pulicidae and Ceratophyllidae. Encounters with *Pulex irritans*, the so-called "human flea," are rare, but humans are often bitten by flea species normally found on animals, e.g., the dog flea (*Ctenocephalides canis*), cat flea (*Ctenocephalides felis felis*), hedgehog flea (*Archaeopsylla erinacei*), and European chicken flea (*Ceratophyllus gallinae*). All flea species show low levels of host specificity and therefore may infest various animal species as well as humans.

Due to their life cycle the sand fleas (family Tungidae) represent a special group of the fleas. *Tunga penetrans*, endemic in tropical Africa as well as Central and South America, is the most important species in this family from a medical point of view. Sand flea infestation is occasionally reported in travelers returning from tropical regions.

Fleas of the Families Pulicidae and Ceratophyllidae

Morphology. The fleas in this group are about 2–5 mm long, laterally flattened, wingless and have three pairs of legs, the hindmost of which are highly adapted for jumping. The mouthparts form a beaklike proboscis for blood-sucking, the antennae are short. Combs of spines (ctenidia) can adorn the head and first thoracic segment (Fig. 11.**1f**).

Life cycle. Fleas are ectoparasites in humans and vertebrate animal species. Frequent blood meals are needed during the one to three month egg-laying period. Most of the eggs fall off the host and continue to develop in cracks and crevices (e.g., between floorboards, under rugs, under dog or cat cushions or in birds' nests). The life cycle from egg to adult includes three larval stages and one pupal stage and takes three to four weeks under ideal conditions. This time period can also be extended by a matter of weeks depending on the environmental conditions. The lifespan of an adult flea varies from a few weeks to one year including longer starving periods as well as egg and pupa survival maxima of eight and five months, respectively. This explains

why dog and cat flea populations can persist in human dwellings for months if control measures are not taken.

Epidemiology. The fleas in this group are periodic ectoparasites. The adult stages remain for the most part on the host while the larvae and pupae live in the vicinity of their hosts in the so-called "nest habitat." In certain regions, fleas serve as vectors for viruses, bacteria, rickettsiae, protozoa, and helminths. Fleas are best-known as the vectors of the causative agent of plague, *Yersinia pestis* (rodent-infesting fleas of the genus *Xenopsylla*, among others).

Clinical manifestations. Dermal reactions to fleabites go through several phases:

- **Early reaction:** within five to 30 minutes after the bite, a dotlike hemorrhage (at the site of the bite) and a reddening (erythema) with or without a central blister are formed, accompanied by pruritus.
- **Late reaction:** after 12–24 hours, itching papules form, surrounded by erythemas up to palm-size, some with a central blister or purulent pustule; this reaction persists for one to two weeks.
- **Predilection sites for lesions:** extremities, neck, nape of neck, shoulders, less often the trunk. Reactions are usually in multiple groups, sometimes in rows.

Diagnosis and control. A diagnosis is reached based on the skin lesions and the case history. Fleas are rarely found on the human body. It is important to find the potential source of flea infestation on animal hosts (dog, cat, hedgehog, birds, etc.) or in their environment, and to identify the fleas found. Once the species is known, specific control measures can be carried out.

Fleas of the Family Tungidae (Sand Fleas)

Tunga penetrans

Causative agent of tungaosis (tungiasis)

Morphology and biology. *Tunga penetrans*, the chigoe, jigger, or sand flea, infest humans and animal species, for example dogs. The males, young females, and other stages live in sandy soil. Fertilized females are highly active in questing for a host. If they succeed, they penetrate the skin head first, then swell up within one to two weeks, sometimes reaching the size of a pea, from their original size of 1–2 mm in length. They lay eggs over a period of about two weeks, and then die while still under the skin.

Clinical manifestations

- Lesions, mainly on the soles of the feet and between the toes, more rarely on other parts of the body.
- Formation of reddened, pea-sized, painful nodules with a craterlike central depression. Inflammatory and sometimes purulent infiltration of the lesion.

Diagnosis, therapy, and prevention. The diagnosis is based on the characteristic skin lesions and can be confirmed by parasitological or histological examination of the material removed from the sores. Treatment consists of mechanical removal of the female flea under local anesthesia and control of the secondary infection. Topical application of ivermectin is also effective. Prevention demands that shoes that fit and close properly be worn.

Appendix to Chapters 9–11

Laboratory Diagnosis of Parasitoses

This section contains short instructions for sampling and shipment of specimens to diagnostic laboratories and describes current options of diagnosing parasitoses. Readers are referred to the specialized literature for more detailed information.

■ In addition to the usual patient data, a diagnostic laboratory requires in particular information on previous stays in foreign countries, especially travel to tropical or developing countries, as well as any clinical symptoms or previous treatments.

Shipment of Materials

Proper shipment of specimens is an important precondition to obtain reliable results! Request specific instructions from officially recognized (accredited) analytical laboratories. The following specimen types are suitable as test materials for the various parasites:

Stool

■ **Intestinal protozoa (*Entamoeba*, *Giardia*, *Cryptosporidium*, *Sarcocystis*, *Cyclospora*, Microspora):** stool specimen preserved in SAF solution. Add about 1 g of fresh (body-warm!) stool to 10 ml SAF solution (**s**odium acetate–**a**cetic acid–**f**ormalin), shake vigorously, and submit to laboratory. If the test result is negative and an infection is still suspected, repeat the test once or twice on different days. Request transport tubes and solution from the laboratory. Commercial test kits are also available for shipment and processing of stool specimens.

Important: treatment with certain drugs may reduce fecal excretion of intestinal protozoa!

■ **Helminth eggs (without *Enterobius*):** one to two specimens of SAF stool, or better yet 10–20 g fresh stool. With larger amounts of fresh stool, concentration methods can be used, thus improving the chances of parasite detection.

■ ***Enterobius* (oxyurid) eggs:** adhesive tape on slide.

In the morning, press the adhesive side of a piece of transparent adhesive tape about 4 cm long and 1 cm wide onto the perianal skin, then strip it off and press the adhesive side smoothly onto a slide. Submit to laboratory or examine under a microscope.

■ **Larvae of** *Strongyloides* or hookworms: about 10–20 g fresh stool (unrefrigerated) for examination using the Baermann technique and for preparing a larval culture.

■ **Coproantigens:** parasite antigens excreted in stool (coproantigens) can be detected using predominantly the ELISA. Laboratory procedures or commercial kits are now available for diagnosing various intestinal parasites, including *Giardia*, *Cryptosporidium, Entamoeba,* and *Taenia*.

Blood

■ **Malaria plasmodia**

Important: the blood specimen must be taken before commencement of malaria therapy, if possible at the onset of a febrile episode. Send the material to the laboratory by the fastest means available!

5–10 ml EDTA blood (to test for *Plasmodium falciparum* antigen, for blood smears and "thick film" preparations).

If possible, add two to four thin, air-dried blood smears (for Giemsa staining and detection/identification of *Plasmodium* species).

■ **Other blood protozoa** (trypanosomes, *Babesia*): 5–10 ml EDTA blood.

■ **Microfilariae:** 5–10 ml blood with EDTA. Important: take blood samples in accordance with periodicity of microfilariae (Table 10.**4**, p. 519), either at night or during the day.

Serum

- **Antibodies to various parasites:** 2–5 ml serum or 5–10 ml of whole blood (both without additives) (see also Table 11.**5**, p. 625).

Cerebrospinal fluid

- **Antibodies to** *Taenia solium* (suspected cysticercosis): 1–2 ml of cerebrospinal fluid, no additives.
- **Trypanosomes:** 1–2 ml of cerebrospinal fluid, no additives.

Bronchial Specimens

- **Microspora and *Pneumocystis carinii*:** induced sputum or 20 ml of bronchial lavage.

Urine

- ***Schistosoma*** eggs and microsporidia: sediment (about 20 ml) from 24-hour urine.

Cultivation

- **Visceral leishmaniosis:** sample obtained under aseptic conditions by puncture from lymph nodes or bone marrow must be transferred immediately to culture medium (order from laboratory).
- **Cutaneous leishmaniosis:** take specimen tissue from the edges of the lesion (following surface disinfection) and transfer to culture medium.
- **Acanthamoebas:** 1–2 ml of contact lens rinsing liquid or conjunctival lavage, no additives.

Material for Polymerase Chain Reaction (PCR)

The PCR (see p. 409) is now used to detect or identify species or strains of different parasites, including for example *Leishmania*, *Toxoplasma*, Microspora, *Echinococcus*, *Taenia*, and filarial worms. For analysis with this technique, the following materials can be sent to the laboratory, depending on the parasite species involved: biopsy or tissue specimens from hosts, blood (with EDTA or heparin added), sputum, fecal specimens or other materials in native condition, and parts of parasites (for example proglottids of *Taenia*). Some specimens can also be fixed in 70% ethanol (consult with the laboratory).

Tissue Specimens and Parasites

- **Skin snip:** for detection of microfilariae in skin. Remove about a 5 mm^2 surface skin specimen using a scalpel and needle, without opening any blood vessels, at the pelvic crest, thigh or other suitable localization, transfer immediately to 0.9% NaCl solution and transport to laboratory immediately or send by express delivery.
- **Surgical preparations and biopsies:** either by standard method fixed in 4% formalin or finished section preparations.
- **Parasites:** place tapeworm parts, trematodes, and nematodes in liquid (physiological saline). Fix arthropods in hot 70% ethanol. Consult with laboratory on sending in other parasites.

Immunodiagnostic and Molecular Techniques

A number of parasitoses can be diagnosed by immunological techniques (detection of antibodies or circulating antigens in serum or of coproantigens in stool) and/or by DNA analysis using the PCR or another technique. Table 11.**5** provides an overview of selected options.

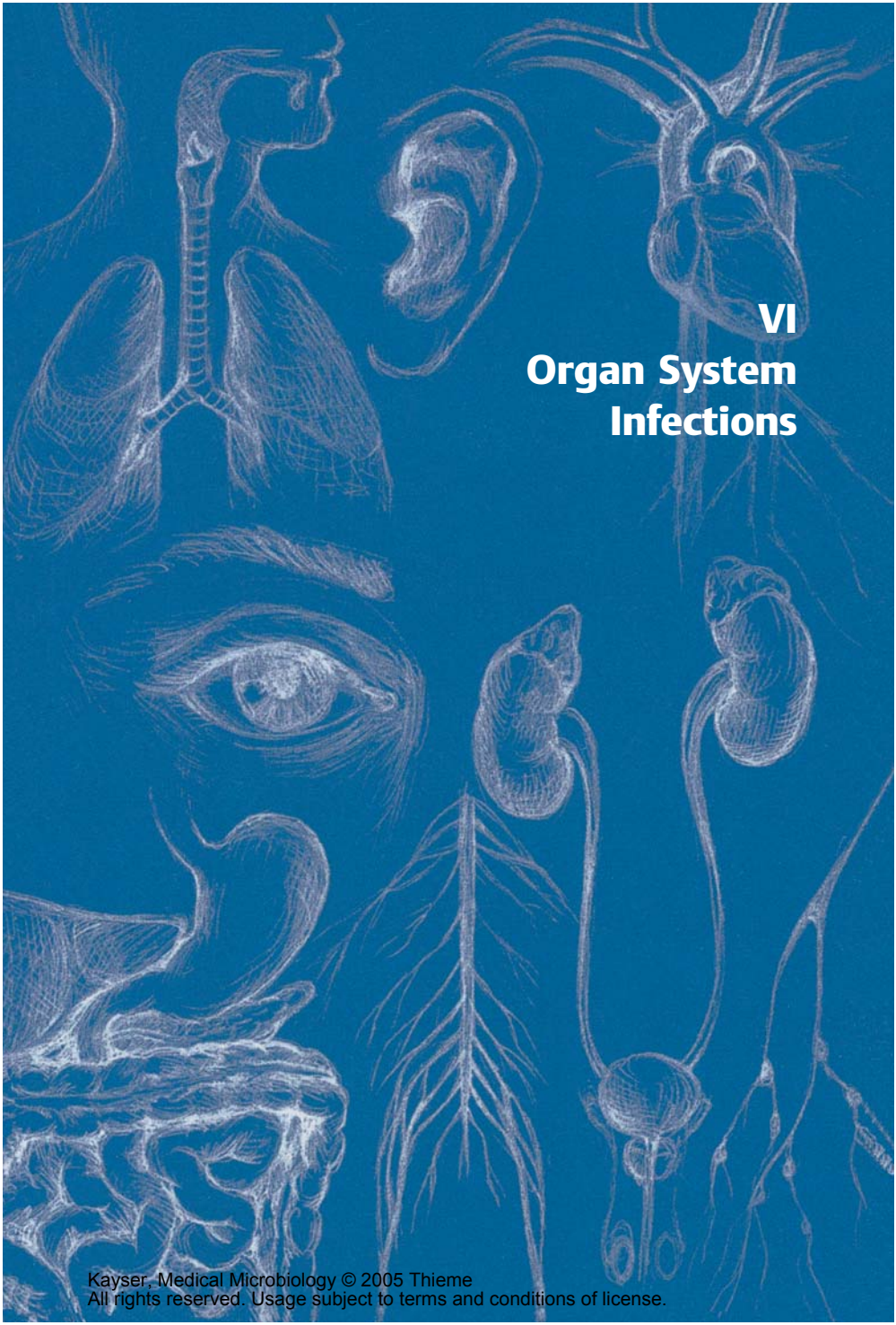
Table 11.5 Immunological and Molecular Diagnosis of Parasitoses in Humans: A Selection of Techniques and Established Methods

Parasitosis	Methods Antibody assay[1]	Antigen assay	DNA analysis
African trypanosomosis (sleeping sickness)	IFAT, ELISA, HA		PCR (blood)
American trypanosomosis (Chagas disease)	IFAT, ELISA, HA		PCR (blood)
Leishmaniosis			
■ visceral	IFAT, ELISA		PCR (blood, lymph node aspirate)
■ cutaneous/mucocutaneous	(IFAT, ELISA)		PCR (biopsy)
Giardiosis		IFAT, ELISA (stool)	
Amebosis (Entamebosis)			
■ intestinal	ELISA, IFAT	ELISA (stool)	PCR (stool)
■ extraintestinal	ELISA, IFAT		
Toxoplasmosis	ELISA, IFAT, SFT, CFT, ISAGA, WB, IgG avidity test		PCR (amniotic fluid, placenta, etc.)
Cryptosporidiosis		ELISA, IFAT (stool)	
Malaria	IFAT	Rapid test (blood)[2]	PCR (blood)
Microsporosis			PCR (stool, urine, etc.)
Schistosomosis	IFAT, ELISA		
Fasciolosis	IFAT, ELISA	ELISA (stool)	
Opisthorchiosis	ELISA		
Paragonimosis	ELISA, HA		
Echinococcosis	ELISA, IFAT, WB		PCR (metacestodes)
Cysticercosis	WB, ELISA		
Taeniosis		ELISA (stool)	PCR (proglottids)
Toxocarosis	ELISA, WB		
Filariosis	ELISA, IFAT	ELISA (serum)	

Table 11.5 *Continued: Immunological and Molecular Diagnosis of Parasitoses in Humans*

Parasitosis	Methods Antibody assay[1]	Antigen assay	DNA analysis
Trichinellosis	ELISA, IFAT, WB		PCR (biopsy)
Strongyloidosis	ELISA, IFAT, WB		
Ascariosis	ELISA		
Anisakiosis	ELISA		

[1] In parentheses: techniques with low reliability.
[2] Rapid test to detect *Plasmodium*-specific antigens or lactate dehydrogenase.
Abbreviations: **ELISA**: enzyme-linked immunosorbent assay, **HA**: hemagglutination, **IFAT**: indirect immunofluorescent antibody test, **ISAGA**: immunosorbent agglutination assay, **CFT**: complement fixation test , **PCR**: polymerase chain reaction, **SFT**: Sabin-Feldman test, **WB**: Western blot (immunoblot).



VI
Organ System Infections

Medical microbiology explores how infectious diseases originate and develop. The focus of this branch of the life sciences is of course on infective pathogens, the causes of infections. This explains why the taxonomy of these microorganisms determines the structure of textbooks of medical microbiology, and this one is no exception. This approach does not, however, satisfy all the requirements of clinical practice. The practicing physician is confronted with a pathological problem affecting a specific organ or organ system, and therefore might well find good use for a brief reference tool covering the pathogenic agents that potentially affect specific organs and systems.

Medical microbiology must address two tasks: 1. describing the origins and development of an infection and 2. obtaining a laboratory diagnosis of the resulting disease that is of immediate clinical relevance to patient treatment. Chapter 12 of this book was written to help bridge the gap between basic microbiological science and the demands of medical practice. Concise information on etiology and laboratory diagnosis has been grouped in tabular form in 12 sections corresponding to the most important organs and organ systems. Infections that affect more than one organ system are listed with the system that is affected most severely and/or most frequently or in which the disease manifests most clearly. The pathogens in question are also listed with the other organ manifestations. In the tables, the most frequent causative pathogens in each case are printed in bold letters. Readers are referred to textbooks on internal medicine or specialist literature on infective diseases for exhaustive information on clinical aspects extending beyond etiology and laboratory diagnosis (see references at the end of the book). The descriptions of the diagnostic procedures used to clarify the different infections had to be kept concise in accordance with the tabular format. Since each laboratory offers its own specific set of testing techniques, a physician's choices are defined and limited by what is feasible and available in a given case. This applies in particular to the many different antibody assays now available (= serology). The most important serological tests are listed together with the relevant pathogens in the respective chapters.