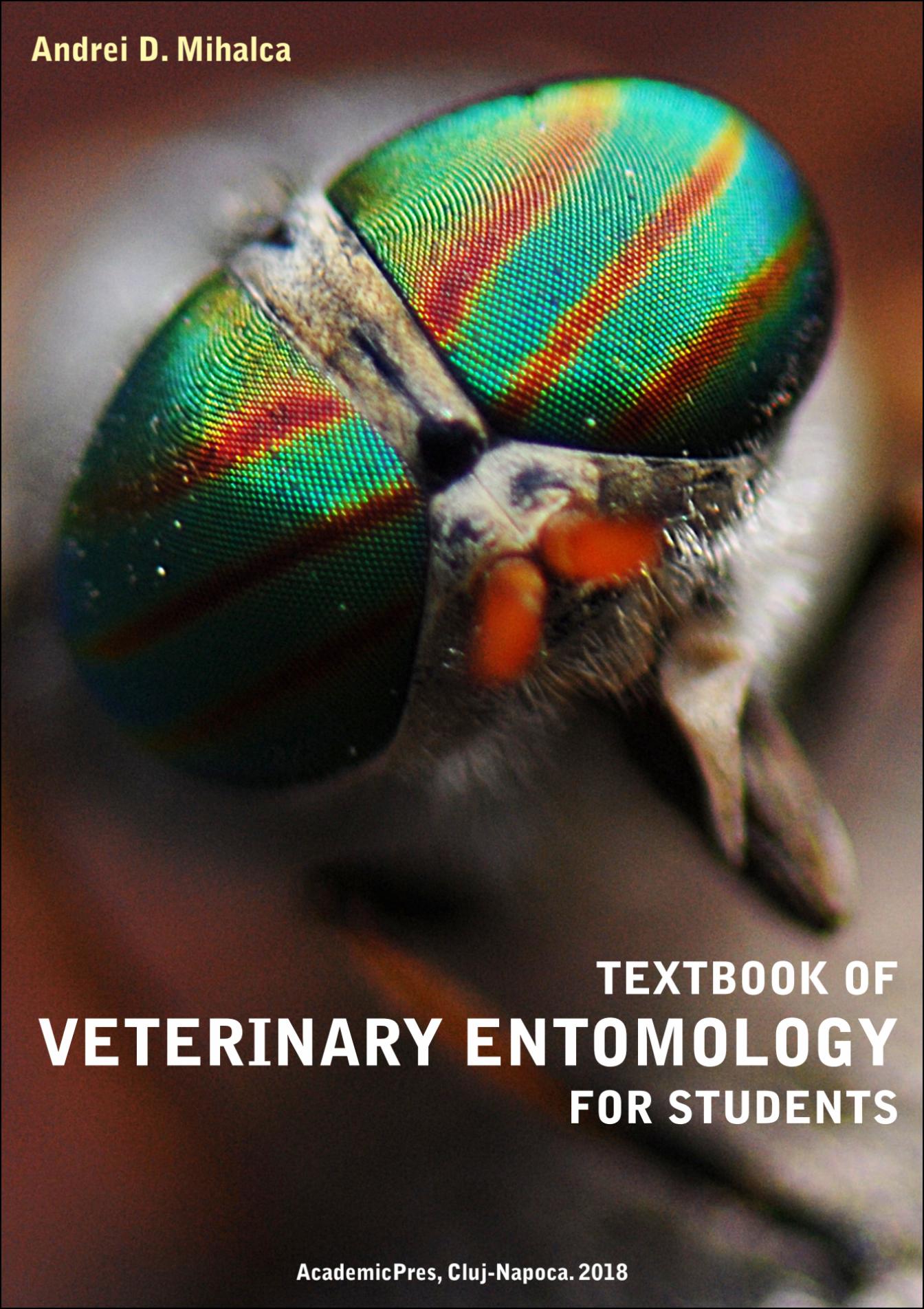


Andrei D. Mihalca



**TEXTBOOK OF
VETERINARY ENTOMOLOGY
FOR STUDENTS**

AcademicPres, Cluj-Napoca. 2018

Andrei D. MIHALCA

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ENTOMOLOGY FOR STUDENTS**

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Table of contents

1. Arthropoda - general features.....	1
2. Arachnida (Acari).....	4
2.1. Ticks.....	5
2.1.1. Hard ticks (Ixodidae)	6
2.1.2. Soft ticks (Argasidae)	19
2.2. Mesostigmatid mites	21
2.2.1. Red poultry mites (Dermanyssidae)	21
2.2.2. Honeybee mites (Varroidae)	24
2.2.3. Other mesostigmatid mites of veterinary importance.....	26
2.3. Prostigmatid mites	28
2.3.1. Demodicidae	28
2.3.2. Fur and quill mites	33
2.3.3. Other prostigmatid mites of veterinary importance.....	34
2.4. Astigmatid mites	35
2.4.1. Psoroptid mange mites	36
2.4.2. Sarcoptid mange mites	42
2.4.3. Knemidocoptid mange mites.....	47
2.4.4. Other astigmatids of veterinary importance.....	50
3. Insecta.....	52
3.1. Lice (Phthiraptera).....	52
3.1.1. Chewing lice	53
3.1.2. Sucking lice	57
3.2. Fleas (Siphonaptera)	60
3.3. Biting Diptera	64
3.3.1. Mosquitoes (Culicidae).....	64
3.3.2. Sandflies (Psychodidae).....	67
3.3.3. Black flies (Simuliidae)	69

3.3.4. Biting midges (Ceratopogonidae)	71
3.3.5. Horse flies (Tabanidae).....	74
3.3.6. Louse flies and keds (Hippoboscidae).....	76
3.4. Myiasis causing Diptera	78
3.4.1. Blow flies and screw-worm flies (Calliphoridae)	79
3.4.2. Flesh flies (Sarcophagidae)	84
3.4.3. Nasal bot flies (Oestrinae)	85
3.4.4. Stomach bot flies (Gasterophilinae)	87
3.4.5. Warble flies (Hypoderminae).....	90
3.4.6. Other agents of myiasis and related species.....	92
3.5. Other dipterans of veterinary importance	93
3.5.1. The bee louse (<i>Braula coeca</i>).....	93
3.5.2. Other groups	94
4. Crustacea	95
4.1. Pentastomida	95
4.1.1. The canine tongue worm (<i>Linguatula serrata</i>)	95
References.....	98

1. Arthropoda - general features

Arthropods are the **most diverse group** of animals on Earth with more than 1,200,000 species described, of which ca. 1,000,000 are insects (Table 1). However, the most recent reviews, estimate that around 80% of the species remain to be described (Stork, 2018). A great number of these are living a parasitic life on several host types (plants, various invertebrates, all vertebrate groups).

Table 1. Diversity of Arthropoda (after Stork, 2018)

Subphylum	Number of species
Chelicerata	111,937
Myriapoda	11,885
Crustacea	66,914
Hexapoda	1,023,559
Total	1,214,295

The branch of parasitology (or branch of zoology) studying the parasitic arthropods is known as **medical entomology** (or veterinary entomology if we refer strictly to the arthropods parasitic on animals).

The greatest importance of parasitic arthropods resides in their capacity of disease transmission, known as **vectorial capacity**, particularly in the blood-sucking species. Nevertheless, most of the parasitic arthropods have also a direct effect on their host, producing **local reactions**, allergies, intoxications or **anaemia**, depending on great variety of factors.

The name of the phylum (Arthropoda) originates from Greek (*ἄρθρον árthron* = joint and *πούς pous* = foot). This

described quite well the main feature of all the groups in this phylum: the presence of **articulated legs**. Arthropods are invertebrates, possessing an external skeleton (**exoskeleton**), a **segmented body** and paired articulated appendages.

The segmentation of the body is the most important feature of all arthropods. In most groups, several segments are joined morphologically and functionally into **tagmata**. This gives the three-body part appearance in insects or the two body parts appearance in spiders or the apparently unsegmented body in mites.

The exoskeleton (also known as cuticle) contains mainly **chitin**, which is a long-chain polymer of N-acetylglucosamine. The exoskeleton is also the site of muscle insertion, which is the primary way of **locomotion** in all mobile arthropods (including flight in many insects). As this structure is rigid, in order to grow, arthropods must undergo **moulting**, also known as ecdysis.

The main **organ systems** of Arthropods are the nervous systems (including sensorial organs), circulatory system, respiratory system, excretory system, and reproductive organs.

The **nervous system** consists in a "brain" (consisting in three pairs of ganglia), located in the head, followed by paired ventral nerve cords forming a chain of paired ganglia in each body segments. Of particular interest for

understanding the control strategies used for arthropods are the **neurotransmitters**. The primary neurotransmitters for the motor neurons in arthropods are the glutamate and GABA (gamma-amino-butyric acid).

The **circulatory system** of arthropods is open and carries the **haemolymph**, which is pumped by a tubular and muscular **heart**.

The **respiratory system** in arthropods is diverse, and largely depends on the main biotope. In aquatic species (e.g. crustaceans), the main organs are the gills, in insects the system is tracheal, while some arachnids have “book lungs”.

The **excretory system** in arthropods is of two main types. In aquatic species (crustaceans), the final product of nitrogen metabolism is ammonia, which is excreted through the gills directly into the water. In terrestrial groups (such as insects), the final product is uric acid, which is eliminated together with the feces.

The vast majority of arthropods are dioecious (i.e. they have separate sexes) and have a **sexual reproduction**. All terrestrial arthropods use internal fertilization. In few groups the male deposit the sperm directly into the female body, while in the majority of terrestrial arthropods, the males produce water-proof packets of sperm (spermatophores), which are later taken by the females into their body. Most arthropods lay eggs, but some species are ovoviviparous. The complete development varies from group to group and is known as **metamorphosis**.

Parasitic arthropods are found on a great variety of hosts, from invertebrates to humans. They inhabit various tissues and organs, but most species are associated with the skin or other cutaneous structures. Two groups of arthropods are particularly important as parasites of domestic animals and humans: **Arachnida** (mites and ticks) and **Insecta** (many groups, see below). Moreover, **Crustacea** include many important species parasitic in aquatic animals, mainly fish.

Most of the species of Arachnida are **parasites of the skin** (i.e. ticks, fur and feather mites, mange mites) but some others have other location: *Acarapis woodi* (honey bee tracheal mite), *Pneumonyssoides* spp. (canine nasal mites).

In the case of insects, certain groups display a **permanent parasitism** (i.e. lice), where all stage are parasitic and are found on the host, while some **others parasitize only as adults** (i.e. fleas) **or only as larvae** (i.e. agents of myiasis). Some species (mainly biting Diptera like mosquitoes) take only short blood meals and spend most of their life off-host. Last but not least, several insect groups are facultative parasite, using a host only in some cases, otherwise being free-living. Most insect species are external parasites, but some (mainly the larval agents of myiasis) parasitize various organs (i.e. *Oestrus* in the nasal cavities of sheep; *Gasterophilus* in the stomach and intestines of horses etc.).

Crustaceans (not further discussed in this textbook) are mainly parasites of fish, and they include species with

important economic impact in aquaculture. *Lernaea* (also known as the “anchor worms”), is a genus of copepod crustacean parasitic in freshwater fish, causing cutaneous lesions and mortality. *Argulus*, another genus of crustacean

parasitic in fish is also an important cause of economic losses in fish farms. One notable exception of a crustacean is *Linguatula serrata*, also known as the canine tongue worm, parasitic in the nasal cavities of dogs.

2. Arachnida (Acari)

Subclass Acari (mites and ticks) includes generally small arthropods, with unsegmented body. The adults and nymphs have 4 pairs of legs while the larvae have three pairs of legs. The anterior part of the body is known as the **gnathosoma** (or **capitulum**) and includes the so-called mouthparts (the pedipalps and the chelicerae) (Wall and Shearer, 1997). The posterior part of the body is known as **idiosoma**, divide into two parts: the **podosoma** (the part where legs are inserted) and the **opisthosoma** (the region behind the legs) (figure 1).

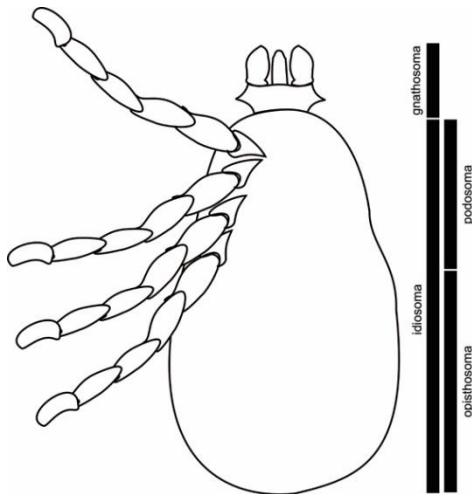


Figure 1. General structure of an Arachnida

As in all Arthropoda, the legs are segmented and usually consist of six segments: **coxa** (the first segment by which the legs are attached to the body), followed by **trochanter**, **femur**, **genu**, **tibia** and **tarsus** (the distal segment)

(figure 2). In some arachnids, at the end of the tarsus other structures can be found: The **pretarsus** which may possess the **ambulacrum**, usually composed of a pair of **claws** (Wall and Shearer, 1997).

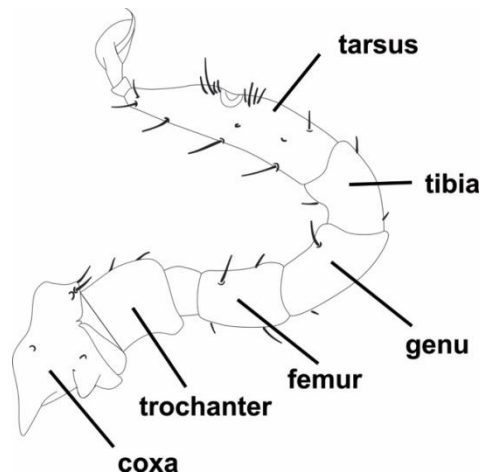


Figure 2. The segments of an Arachnid leg

Arachnid respiration may take place through the **stigmas** (one to four pairs), porose structures located on the idiosoma. In some mites, stigmas are absent (Astigmata) and the respiration takes place directly through the integument. The idiosoma is covered with **setae** (hairs), which have sensorial role (Wall and Shearer, 1997).

The life cycle consists of the adult stages (males and females), eggs, larvae and nymphs (one or more nymphal stages, depending on the group). **In mites**, usually the females produce relatively large eggs, from which the hexapod

larvae hatch. In some groups of mites, females are ovoviviparous (the eggs hatch inside the females) and live larvae are born. The larvae moult into eight-legged nymphs. Depending on the mite group, there can be one, two or three nymphal stages (protonymph, deutonymph, tritonymph). The nymphs moult into adults. The total duration of the cycle in mites is usually less than 4 weeks. In ticks the life cycle consists in the following stages: eggs, one larval stage, one or more nymphal stages and one adult stage (males and females).

Acari are primarily classified according to the position/existence of their respiratory structure (the stigma) into four main groups: Metastigmata (ticks), Mesostigmata (i.e. *Dermanyssus*, *Varroa*), Prostigmata (i.e. *Demodex*, *Cheyletiella*, *Neotrombicula*) and Astigmata (i.e. mange mites). There are more than 30000 species of Acari known, of which the most important medically important groups are the ticks, the mange mites, the poultry mites, the bee mite, chigger mites and several other fur or skin mites.

2.1. Ticks

Ticks are obligate blood-sucking arthropods, with a worldwide distribution, parasitic on all groups of terrestrial vertebrates, more commonly on terrestrial reptiles, birds and mammals and occasionally on amphibians and aquatic reptiles. Their medical and veterinary importance resides mostly in their capacity to transmit a huge variety of pathogens

(viruses, bacteria, protozoans, helminths) which cause the so called tick-borne diseases. Ticks rank first within the disease vectors as regards the variety of transmitted pathogens and are second only to mosquitoes considering their public health importance (Sonenshine et al. 2002). Historically, ticks were the first blood-sucking arthropods to be demonstrated as being able to transmit pathogens (the discovery of the transmission of *Babesia bigemina* by ticks to cattle by Smith and Kilbourne from the end of the XIX Century). This monumental discovery opened new avenues in medical research and several tremendously important diseases have been demonstrated to be transmitted by hematophagous arthropods in the following years. Following these discoveries, new control and prevention methods begun to be implemented for reducing the impact of vector-borne disease in humans and animals.

Except their vectorial role, ticks may have local pathogenic effect, causing skin lesions or, more rarely, systemic effects (tick paralysis or anaemia). Last but not least, ticks cause significant economic losses in the livestock industry due to decreased production and are responsible for considerable amount of revenues for the pharmaceutical industry due to expenses for their control.

Around 900 species of ticks are currently known, included in three families: Ixodidae (hard ticks) (702 species in 14 genera), Argasidae (soft ticks) (193 species in 5 genera) and

Nuttalliellidae (1 genus with one species) (Guglielmone et al. 2010). Ticks have a wide geographic distribution, with the highest diversity between the tropics, but some species are present even beyond the polar circle.

2.1.1. Hard ticks (Ixodidae)

Hard ticks represent the most diverse group of ticks and they have some unique features which differentiate them from soft ticks, most notably the presence of a hard, dorsal shield (hence the name) and the single blood meal for each of the three developmental stages.

Taxonomy. There are more than 700 species of hard ticks known, distributed in 14 genera. The most important genera of medical and veterinary importance are *Ixodes*, *Dermacentor*, *Haemaphysalis*, *Rhipicephalus*, *Hyalomma*, and *Amblyomma*. The other genera have a minor medical importance.

Based on the position of the anal groove, the hard ticks are divided into two main groups: (i) the Prostriata, with the anal groove encircling the anus anteriorly (*Ixodes*) and (ii) the Metastriata, with the anal groove encircling the anus posteriorly (*Hyalomma*, *Dermacentor*, *Haemaphysalis*, *Rhipicephalus*, and *Amblyomma*). The veterinary important species of are listed in table 2.

Genus *Ixodes* is the most biodiverse genus of the hard ticks, with 245 species described and a worldwide distribution (including several cold tolerant species). The most important species are *Ixodes ricinus* (figures 3 and 4), *I. hexagonus* (figure 5), and *I. persulcatus* (in Europe

and parts of Asia), *I. scapularis* and *I. pacificus* (in North America) mainly because of their role as vectors for several human or animal pathogens (see table 2 for details). Another important species is *Ixodes holocyclus* which causes a severe paralytic syndrome (known as the tick paralysis) (Guglielmone et al. 2014).

Genus *Dermacentor* is a relatively small genus (it includes around 35 species) but with important and widely distributed representatives, important vectors for human and animal diseases (see table 2 for details). Several species are important veterinary ectoparasites: *D. marginatus* (figure 7), *D. reticulatus* (in Europe and Asia), *D. silvarum* and *D. nuttalli* (in Asia), *D. andersoni*, *D. variabilis*, *D. occidentalis*, and *D. albipictus* (in North America) and *D. nitens* (in South America) (Deplazes et al. 2016).

Genus *Hyalomma* includes 27 species distributed mainly in Africa, Asia and Southern Europe. The most important species from medical point of view are *H. marginatum* (figure 8) (in southern Europe, northern Africa and parts of Asia) and *H. anatolicum* (in Africa and Asia) (Estrada- Peña et al. 2018). The most important tick of dromedaries is *H. dromedarii* (figure 9).

Genus *Amblyomma* includes ca. 130 species, distributed mainly in tropical areas. The most common are *A. hebraeum* (South Africa), *A. variegatum*, *A. gemma* (Africa), *A. americanum*, *A. maculatum* (USA) and *A. cajennense* (the Americas) (Deplazes et al. 2016).

Table 2. Representative species of hard ticks, their main hosts and geographic distribution

Species*	Main hosts	Main pathogens transmitted**	Zoogeography
<i>Ixodes ricinus</i>	small mammals, birds, lizards, cattle, deer, other mammals	Tick-borne encephalitis virus, louping-ill virus, Eyach virus, Tribec virus, <i>Borrelia burgdorferi</i> s.l., <i>Borrelia miyamotoi</i> , <i>Rickettsia slovaca</i> , <i>R. helvetica</i> , <i>R. monacensis</i> , <i>Anaplasma phagocytophilum</i> , <i>Babesia divergens</i> , <i>B. microti</i> ,	Palearctic
<i>I. hexagonus</i>	hedgehogs, carnivores	<i>Borrelia burgdorferi</i> s.l., <i>Theileria annae</i>	Palearctic
<i>I. persulcatus</i>	small mammals, deer, cattle, sheep, hares	<i>Borrelia burgdorferi</i> s.l., <i>R. helvetica</i> , <i>R. japonica</i> , <i>R. sibirica</i> , <i>Anaplasma phagocytophilum</i> , <i>Ehrlichia muris</i> , <i>Babesia microti</i>	Palearctic, Oriental
<i>I. scapularis</i>	small mammals, deer	<i>Borrelia burgdorferi</i> s.l., <i>Borrelia miyamotoi</i> , <i>Theileria microti</i> , <i>Anaplasma phagocytophilum</i>	Nearctic, Neotropical
<i>I. holocyclus</i>	dogs, humans	<i>Rickettsia australis</i> , <i>Coxiella burnetii</i>	Australasian
<i>Dermacentor reticulatus</i>	small mammals, lagomorphs, ungulates, carnivores	tick-borne encephalitis virus, Omsk haemorrhagic fever viruses, <i>Rickettsia sibirica</i> , <i>R. raoultii</i> , <i>Babesia canis</i> , <i>B. caballi</i> , <i>Theileria equi</i>	Palearctic
<i>D. marginatus</i>	small mammals, lagomorphs, ungulates, carnivores	tick-borne encephalitis virus, Crimean-Congo haemorrhagic fever virus, Omsk haemorrhagic fever virus, <i>Rickettsia sibirica</i> , <i>R. slovaca</i> , <i>R. conorii</i> , <i>Babesia caballi</i> , <i>Theileria equi</i>	Palearctic
<i>D. andersoni</i>	small mammals, dogs,	<i>Rickettsia rickettsii</i> , <i>Francisella tularensis</i>	Nearctic
<i>Haemaphysalis punctata</i>	small mammals, birds, , hedgehogs, ungulates	louping-ill virus, <i>Babesia bigemina</i> , <i>B. major</i> , <i>B. motasi</i>	Palearctic
<i>H. concinna</i>	small mammals, birds, ungulates, carnivores, hedgehogs	<i>Rickettsia heilongjiangensis</i> , <i>R. sibirica</i> , <i>R. helvetica</i> , <i>Anaplasma phagocytophilum</i> , <i>A. bovis</i> , <i>Coxiella burnetii</i> , <i>Francisella tularensis</i>	Oriental, Palearctic
<i>H. elliptica</i>	dogs, cats, wild carnivores	<i>Babesia rossi</i>	Afrotropical
<i>Rhipicephalus sanguineus</i>	dogs, small vertebrates	<i>Babesia vogeli</i> , <i>Ehrlichia canis</i> , <i>Hepatozoon canis</i> , <i>Rickettsia conorii</i> , <i>R. rickettsii</i>	Worldwide
<i>R. microplus</i>	cattle, other ungulates, horses	<i>Babesia bigemina</i> , <i>B. bovis</i> , <i>B. equi</i> , <i>Anaplasma marginale</i>	Worldwide
<i>R. bursa</i>	sheep, goats, cattle, horses, donkeys	<i>Babesia ovis</i> , <i>Anaplasma ovis</i> , <i>A. marginale</i> , <i>A. centrale</i>	Palearctic
<i>R. annulatus</i>	cattle, sheep, goats, wild ungulates	<i>Babesia bigemina</i> , <i>B. bovis</i> , <i>Anaplasma marginale</i>	Afrotropical, Nearctic, Palearctic
<i>Hyalomma marginatum</i>	small mammals, birds, wild and domestic ungulates	Crimean-Congo haemorrhagic fever virus, <i>Anaplasma marginale</i> , <i>Babesia bigemina</i> , <i>B. bovis</i> , <i>B. caballi</i> , <i>Theileria annulata</i>	Palearctic
<i>H. anatolicum</i>	cattle, sheep, goats, camels, horses	Crimean-Congo haemorrhagic fever virus, <i>Theileria annulata</i> , <i>T. lestoquardi</i> , <i>T. equi</i> , <i>Babesia caballi</i>	Afrotropical, Oriental, Palearctic

*Species in bold are commonly found also on humans and/or are important vectors for human tick-borne diseases

**For some pathogens listed here, the vectorial capacity is only suspected



Figure 4. Adult female of *Ixodes ricinus*. Note the ventrally placed male (photo Andrei D. Mihalca)



Figure 6. Female of *Ixodes hexagonus* (photo Andrei D. Mihalca)



Figure 5. Nymph of *Ixodes ricinus* (photo Andrei D. Mihalca)



Figure 7. Questing female of *Dermacentor marginatus* (photo Andrei D. Mihalca)

Genus *Haemaphysalis* includes around 167 species, with a worldwide distribution. The most important species are *H. punctata* (in Europe, parts of Africa and Asia), *H. concinna* and *H. inermis* (Europe and Asia), and *H. elliptica* (Africa) (Guglielmone et al. 2014).

Genus *Rhipicephalus* contains ca. 84 species, with a worldwide distribution. Several species have medical importance, the most important being: *R. sanguineus* (worldwide) (figure 10), *R. bursa* (Mediterranean region), *R. turanicus* (Europe, Middle East, North Africa) and *R. microplus* (worldwide) (Guglielmone et al. 2014).



Figure 8. Male of *Hyalomma marginatum* crawling on a human patient (photo Andrei D. Mihalca)



Figure 10. Massive parasitism with *Rhipicephalus sanguineus* on a domestic dog (photo Andrei D. Mihalca)



Figure 9. Massive parasitism with *Hyalomma dromedarii* (photo Andrei D. Mihalca)



Figure 11. Engorged female vs. non-engorged male of *Ixodes ricinus* (photo Andrei D. Mihalca)

Morphology. Hard ticks have relatively similar morphology, regardless their stage, except the size (with larvae the smallest and adult females the largest). Their size also varies with the species, but mainly with the level of engorgement with blood. The body weight can increase 200 times in an engorged female (figure 11).

Larvae have three pairs of legs, while nymphs and adults have four pair of legs. The main difference between nymphs and adults consists in the absences of the genital opening in the former. Larvae and nymphs are not sexually dimorphic, while the adults can be easily differentiated in males and females based on the size of the dorsal scutum (complete in males, incomplete

in females, to allow feeding) (figure 13). The gnathosoma includes the basis capituli, two palps, two chelicerae and one hypostome (figure 12). The chelicerae are used to cut the skin, and the hypostome, which is armed with several rows of backward teeth is used for the attachment. Some ticks have eyes, located on the lateral sides of the scutum. Other important morphological features are the stigmata, which are located posteriorly to the coxa of the last pair of legs. On the ventral side, other features are visible: the genital opening (only in adults), the anal opening, the anal groove and various plates. Based on all these features, hard ticks can be easily identified to genus level. A simple pictorial key for adults is shown in figure 14.

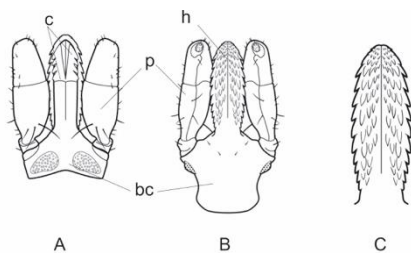


Figure 12. Details of the Gnathosoma of a hard tick. A - dorsal view; B - ventral view. C- detail of the hypostome; p - palps; c - chelicerae; h - hypostome; bc - basis capituli (adapted from Estrada- Peña, Mihalca and Petney, 2018)

Biology and life-cycle. All hard ticks and all stages are **hematophagous**. In some species, males do not feed. There are four developmental stages: eggs, larvae, nymphs and adults. Depending on the number of hosts used by a tick to complete its life cycle, there are three main types: three-host ticks (the

majority of species), two-host ticks, and on-host ticks. The following description of events is detailed for the **three-host ticks** (figure 15). The fully engorged female (figure 15-17) detaches from the host (figure 15-16), looks for a sheltered microhabitat where it lays (figure 15-1) a single batch of eggs (up to 5000) (figure 15-2). After oviposition, the female dies. Under optimal environmental conditions, the eggs hatch (figure 15-3), depending on the species, in several weeks.

The larvae (figure 15-4) look for a host, attach (figure 15-5), feed for several days and detach (figure 15-6). In the environment, they digest the ingested blood (figure 15-7) and moult (figure 15-8) to become an unengorged nymph (figure 15-9).

The nymph will eventually attach to a second host (figure 15-10), feed for 4-8 days, detach (figure 15-11) and digest the blood meal in the environment (figure 15-12). The nymphs will undergo the last moulting (figure 15-13), becoming adults (figure 15-14).

In some ticks of genus *Ixodes*, the mating takes place before the attachment, in the environment. However, in most other ticks, the mating takes place on the host, after the females start feeding. Males use their mouthparts to stimulate the females. The hypostome and chelicerae are inserted in the genital opening of the female when the spermatophores is transferred.

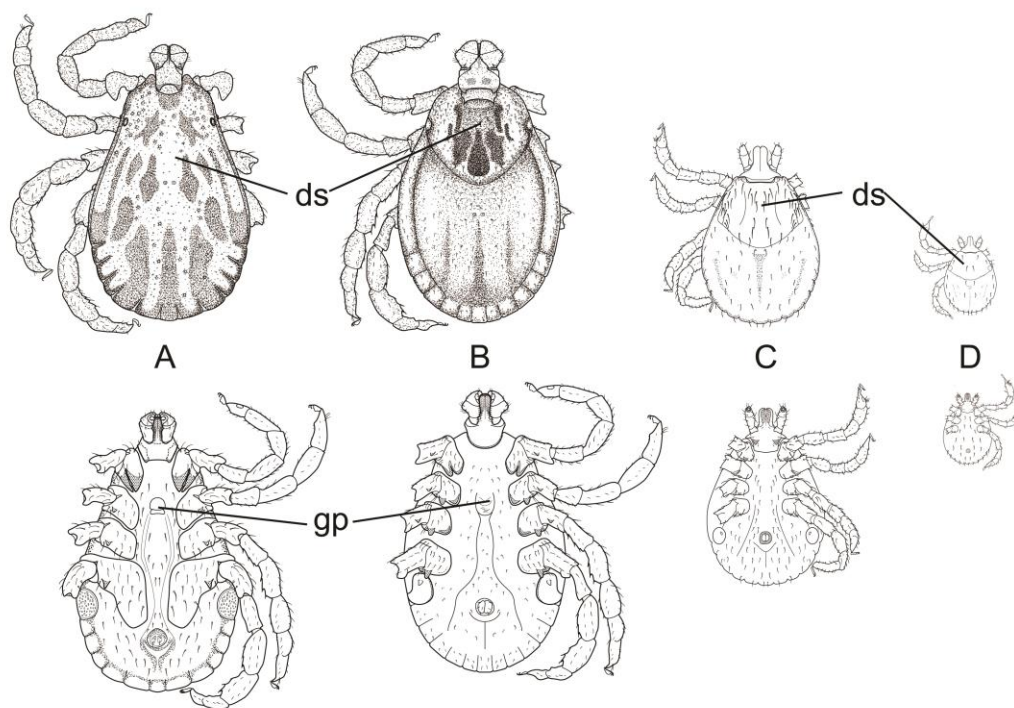


Figure 13. Main morphological features for differentiating the stages and sexes of hard tick. A - male; B - female; C - nymph; D - larva. Upper row - dorsal view; Lower row - ventral view. Note the presence of the genital pore (gp) only in adults (males and females). Note the incomplete dorsal scutum (ds) in larvae, nymphs and adult females and the complete dorsal scutum in adult males. Note the number of legs (4 in males, females and nymphs and 3 in larvae) (adapted from Estrada- Peña, Mihalca and Petney, 2018)

After the female is fully engorged (figure 15-17), it will detach, fall to the ground (figure 15-16) where it will lay the eggs and die. In most temperate species, this life cycle lasts between 2 and 4 years, with 95% of the tick's life spent off-host. In tropic regions, several generations per year are possible, while in areas with cold climate, the life cycle can extend up to 7 years.

As mentioned before, the majority of ticks undergo a life cycle as the one described above, with three hosts (one for each stage). However, there are several tick species which need only **two hosts** to complete their life cycle. In

these, the larva and the nymph use the same host, and the first moulting occurs while the engorged larva is still attached. This type of life cycle is seen in *Rhipicephalus evertsi*, *R. bursa* or *Hyalomma marginatum*. Last but not least, other ticks follow a **one-host life cycle** (i.e. *Rhipicephalus microplus*, *R. annulatus*). In this case, all the stages feed and moult on the same host, and only the adults are detaching.

Another important aspect of tick biology is related to the host-finding behaviour. There are three main types of strategies used by tick to find their host. Some ticks have a **questing** behaviour.

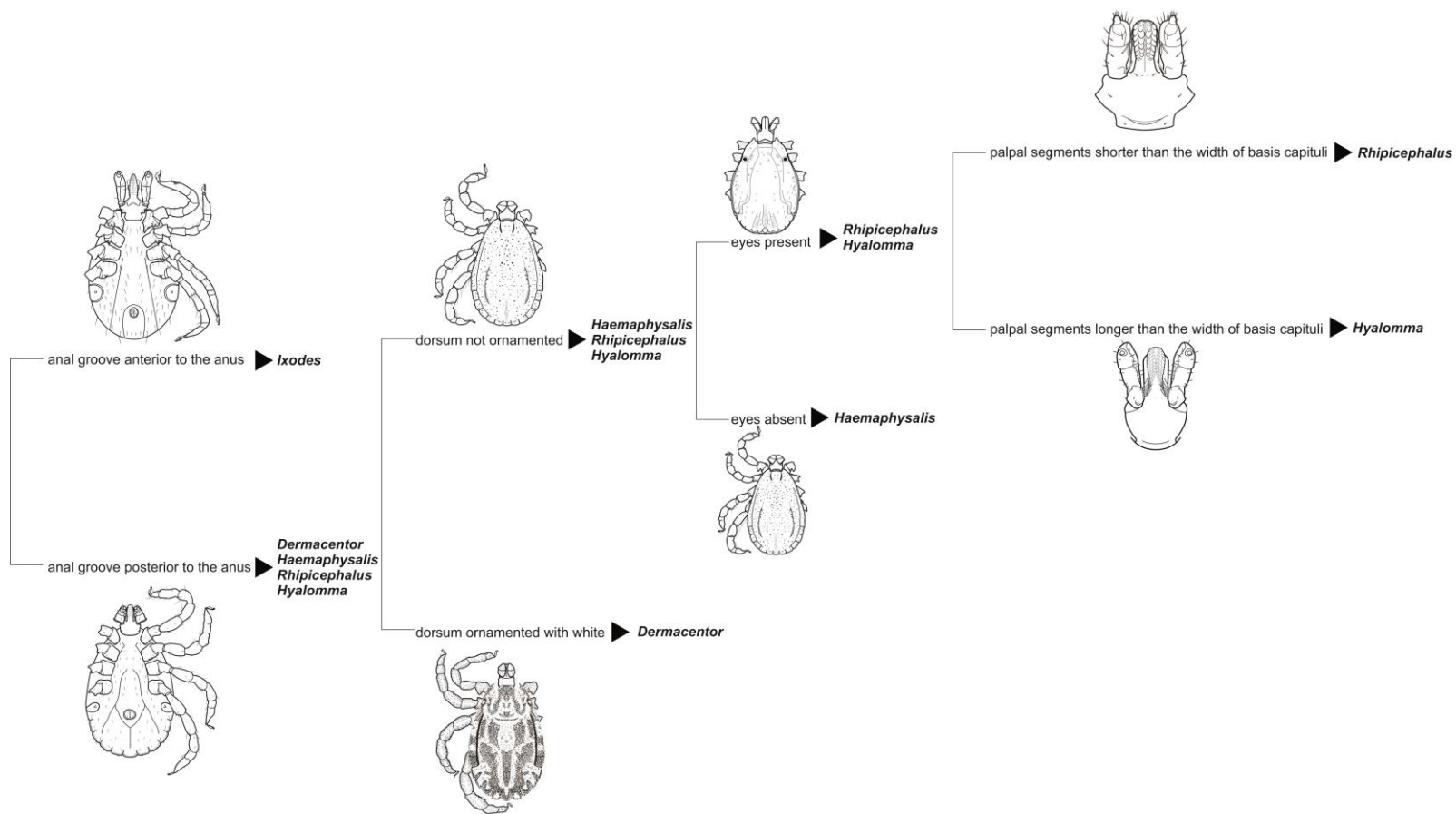


Figure 14. Pictorial key for the identification of the adults to the main genera of hard ticks (adapted from Estrada- Peña, Mihalca and Petney, 2018)

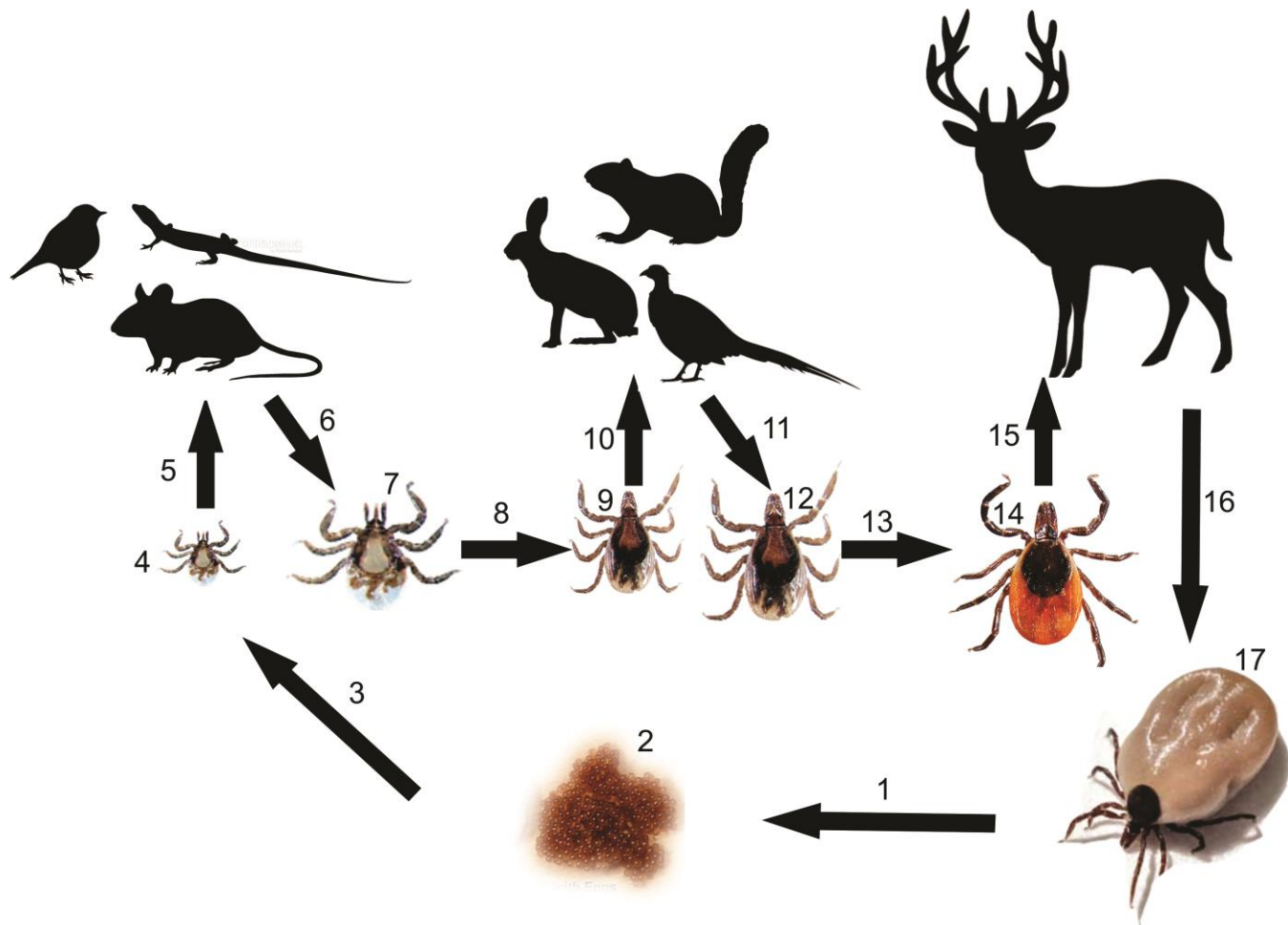


Figure 15. The life cycle of a three-hosts tick (see text for details)

They passively wait on the vegetation for a host to pass (e.g. *Ixodes ricinus*). Other ticks, are actively **hunting** for their host (i.e. *Hyalomma marginatum*), and many other **co-inhabit the burrow** of their hosts (i.e. birds tick like *Ixodes arboricola* or the hedgehog tick, *Ixodes hexagonus*).

Host specificity in ticks is also variable. Some species are generalists, feeding on a great variety of hosts. For instance, *Ixodes ricinus* uses more than 300 vertebrate species. However, immature stages prefer small sized vertebrates like micromammals (figure 16), birds (figure 17) or lizards (figure 18). Some other ticks are host specific, and all stages feed almost exclusively on a certain host. For instance, the adults of *Hyalomma aegyptium* prefer tortoises (figure 19), while larvae can feed also on various rodents.



Figure 16. Nymph of *Ixodes* sp. on a shrew (photo Andrei D. Mihalca)



Figure 17. Engorged nymphs of *Ixodes ricinus* feeding on a bird (photo Andrei D. Mihalca)



Figure 18. Engorged larvae and nymphs of *Ixodes ricinus* feeding on a bird (photo Ioan Ghira)

Epidemiology. In general, ticks have a worldwide distribution, but their diversity, abundance and seasonality are different across the globe. Certain ticks are adapted to humid environments, others to more arid. There are ticks which are found in forested habitats (i.e. *Ixodes ricinus*), while others prefer open areas like steppe (i.e. *Rhipicephalus rossicus*).



Figure 19. *Hyalomma aegyptium* on a Greek tortoise (photo Andrei D. Mihalca)

Many ticks spread far away from their original distribution area and became invasive due to human activities and animal migration. For instance, *Rhipicephalus microplus* has spread from Asia to Africa, Australia and the Americas.

As ticks spend most of their time in the habitat, their distribution and seasonality is highly dependent on environmental conditions, mainly temperature, humidity and type of vegetation, but also on the availability and abundance of hosts. In general, different tick species have different seasonal activities, which may be different for the same tick species in different geographic areas.

Immunology. The immune reactions related to the tick bite are important, as they are responsible for the local reaction but they also interfere with the pathogen transmission. Moreover, they have a practical importance for the development of anti-tick vaccines.

The tick **saliva** is inoculated into the host after the attachment. Compared to other hematophagous arthropods, the contact between the tick (and its saliva) and the host is extremely long (days or weeks in ticks compared to minutes in mosquitoes), hence exacerbating the local reactions. The saliva of ticks has very complex composition and functions. First, the tick eliminates the **excess of water** and ions from the host's blood. In several species (i.e. *Rhipicephalus microplus*), the saliva is rich in proteolytic enzymes, creating extensive lesions which favour the "pool feeding" in these species. The saliva has also an **anti-haemostatic** effect, various components produced by the tick being able to counteract the platelet aggregation, vasoconstriction or clotting cascade. The saliva and other products of the tick (e.g. the cement) also **inhibit the local inflammation** by inhibition of skin reaction or anti-histamine activity. An interesting property of the tick saliva is the **anaesthetic effect**. The carboxypeptidase from the tick saliva inactivates the bradykinin, which is responsible for the local pain. Hence, the vast majority of tick bites are not painful and prevent grooming and tick removal by the host. Tick bites are also associated with allergic reactions (type I and type IV) (Deplazes et al. 2016).

In some ticks, a partial immunity to tick saliva develops after repeated infestations, but this is known only in certain tick species and lacks in others. Local breeds can show an increased resistance to tick bite (decreased engorgement success, higher tick

mortality, lower infestation rates, lower reproductive success of ticks, etc.), like in the case of tropical cattle (Zebu) (Deplazes et al. 2016).

Disease. Ticks are responsible for a great variety of conditions, varying from local to systemic, from inapparent to severe, or even deadly. **Local lesions** occur often at the site of the bite. The trauma is produced by the penetration of the tick's mouthparts, and in species with large gnathosoma, these can be significant. Moreover, some ticks burry themselves deep into the skin (figure 20), causing more severe lesions. An unusual situation has been found in red foxes, with large numbers of dead tick found in the subcutaneous tissue (D'Amico et al. 2017). The typical local lesions and signs associated with the tick bite include hyperaemia, erythema, itching, necrosis, ulcerations, bleeding, thickening of the skin, formation of nodules and granulomas (figure 21) (Deplazes et al. 2016).



Figure 20. Tick deeply buried in the skin (photo Andrei D. Mihalca)



Figure 21. Hypertrophic skin reaction in the perineal region of a camel with heavy infestation with *Hyalomma dromedarii* and *Rhipicephalus pulchellus* (photo Andrei D. Mihalca)

Certain tick species have preferences for particular body regions, where the skin is thinner (like the head or the ear pinna) or where they are more protected (axillary region or ear) (figures 22-24).



Figure 22. *Ixodes hexagonus* immature stages around the eye of a hedgehog (photo Andrei D. Mihalca)



Figure 23. *Rhipicephalus sanguineus* in the external ear of a dog (photo Andrei D. Mihalca)



Figure 24. *Rhipicephalus sanguineus* around the eye of dog (photo Andrei D. Mihalca)

Other local, but severe lesions occur when a high number of tick infest appendices like the tail, producing a severe ischemia, followed by necrosis.

During infestation with certain tick species, **systemic effects** are also present. The most important is the **toxic effect**, which can be specific or non-specific. The former, has been described

in European breeds of cattle when they are kept in tropical regions and are parasitized by high numbers of local ticks. The massive skin damage leads to secondary infection and metabolic disorders. The specific tick toxicoses have been described for several tick species. *Hyalomma truncatum* is responsible for the so-called **sweating sickness**. This condition is an acute tick-related toxicosis found in calves, sheep, goats and pigs from South Africa and India. The associated symptoms are: sweating, excessive lacrimation and salivation, diphtheroid stomatitis and severe dermatitis (Deplazes et al. 2016).

The **tick paralysis** is a severe, sometimes life-threatening toxic reaction of animals and humans associated with the bites of around 50 species of ticks. It is caused by the presence of neurotoxins from the saliva of such ticks, which prevent the release of acetylcholine and block the neuromuscular junctions. Examples of ticks able to produce tick paralysis are: *Dermacentor andersoni* and *D. variabilis* in grazing animals, pets and humans from USA, *Rhipicephalus evertsi* and *Ixodes rubicundus* in sheep and goats from South Africa and *Ixodes holocyclus* in various hosts, including humans in Australia (Deplazes et al. 2016).

High numbers of tick can induce **anaemia** and significantly **decrease milk production** in cattle, making them parasites with a great economic importance.

Vectorial role. Due to their particular and complex biology and alternation of various hosts, ticks are vectors to a

plethora of pathogens, including viruses, bacteria, protozoa and even helminths. However, the vectorial capacity and competence varies between species, and some tick-pathogens associations are relatively specific. For a list of the most important pathogens vectored by various tick species, see table 2.

Tick can be mechanical vectors (but this is rare) or biological vectors (the typical situation). Biological transmission occurs when ticks inoculate to a new host the pathogens acquired during the feeding in a previous developmental stage and from a previous host. Hence, such transmission is possible only if the pathogen is able to survive the moulting, situation known as **transstadial transmission** or passage. The transstadial transmission can persist for several generations without further infections from a host. Another important condition for the vectorial capacity is the **transovarial transmission**. When an adult female feeds on an infected host, the pathogen will survive in the epidemiologic chain only if it is able to pass through the ovaries to the eggs. Other mechanisms of tick infestation with pathogens are by co-feeding or sexually, during mating.

Some tick-borne pathogens are transmitted following ingestion of tick by a susceptible host, like the case of *Hepatozoon canis* or *H. americanum* in dogs.

Diagnosis. The presence of ticks is generally easily noticed even by the owners, mainly when adult and partly engorged ticks are present. However, the presence of larvae or nymphs can be

overlooked even by experienced personnel. Areas of predilections should be checked more thoroughly (head, ear pinna, periocular regions and eyelids, axillary region, perianal region and external genitalia, mammary glands, inguinal region, interdigital space).

Treatment and control. Control of ticks is essential for prevention of tick-borne diseases. The most controversial aspect related to the on-host control of ticks is related to the pathogen transmission. Most pharmaceutical products being able to kill ticks require the tick feeding on the treated host. Hence, the lethal effect on ticks follows an initial blood meal. If the tick is able to transmit a pathogen during this blood meal remains a question for many pathogens. Recently, new drugs have developed which prevent the tick from feeding (anti-feeding effect) and which have a certain repellent effect.

In dogs, the following combinations are approved and commercially available:

- **collars:** deltamethrin, flumethrin + imidacloprid
- **spot-on:** fipronil, fipronil + methoprene + amitraz; imidacloprid + permethrin; metaflumizone + amitraz; permethrin
- **per os:** fluralaner; sarolaner

In cats:

- **collars:** flumethrin + imidacloprid
- **spot-on:** fipronil

In ruminants:

- **pour-on:** flumethrin, deltamethrin, eprinomectin

- **spray/dip:** phoxim, diazinon, amitraz, cypermethrin
- **injection:** ivermectin
- **per os:** abamectin

In several countries, vaccines against *Rhipicephalus microplus* are commercially available and successfully used.

2.1.2. Soft ticks (Argasidae)

Soft ticks are less common and less known compared to hard ticks, but certain species are important cause of disease and important vectors.

Taxonomy. The soft-ticks are included in the family Argasidae. Almost 200 species are known, divided into 5 genera. Three genera are of veterinary importance: *Ornithodoros* (with 114 species), *Argas* (with 61 species) and *Otobius* (with 2 species). Most species of *Argas* are parasitic on birds and bats. *Argas reflexus* is a parasite of pigeons across the Palearctic region (Europe, Asia, and North Africa). *Argas persicus* is a parasite of domestic fowl (hen, turkey, ducks, geese, etc.), with a worldwide distribution. Other species of medical and/or veterinary importance are *Ornithodoros moubata* (found in arid regions of Africa on chicken, pigs, humans, etc.), *O. savignyi* (arid regions of Africa on camels, cattle, equids, humans) and *O. erraticus* (many mammalian hosts, including humans; distributed in the Iberian Peninsula, north and west Africa, west Asia) (Russell et al. 2013; Deplazes et al. 2016; Estrada-Peña et al. 2018).

Morphology. The name “soft ticks” refers to the absence of the dorsal scutum, which is in turn present on the body of Ixodidae (hard ticks). As a consequence, males and females are not easily distinguishable (Deplazes et al. 2016). In adults and nymphs, the capitulum is in ventral position and is not visible from dorsal view (figures 25-27). In larvae, the capitulum is terminal, like in hard ticks.

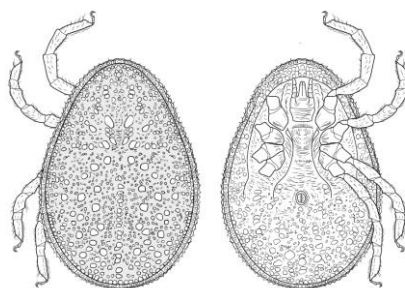


Figure 25. Dorsal (left) and ventral (right) view of *Argas persicus* (from Estrada- Peña, Mihalca and Petney, 2018)



Figure 26. Dorsal view of *Argas persicus* (photo Andrei D. Mihalca)

The body has a leathery aspect and in unengorged specimens, it can have a wrinkled or folded aspect. The stigmata are small and located anteriorly to the coxae of the fourth pair of legs. Eyes are absent in the majority of species (Russell et al. 2013; Deplazes et al. 2016).



Figure 27. Ventral view of *Argas persicus* (photo Andrei D. Mihalca)

Biology and life-cycle. Soft ticks have a very different biology than hard ticks. They have one larval stage, followed by several nymphal stages (two to eight) and adults (males and females). Each immature stage feeds once, but adults are feeding multiple times. Larvae of most *Argas* species remain attached to the host for one week, while larvae of majority of *Ornithodoros* do not feed. Adults mate off-host. Females lay batches of 400-500 eggs after each blood meal. Unlike hard ticks, the feeding is short (20-30 minutes). Adult females of *Otobius megnini* do not feed. The total duration of the cycle can reach up to 14 years and some species can survive

without feeding for 5-7 years (Russell et al. 2013; Deplazes et al. 2016).

Most species complete their life cycle in the nest of their host, living when off-host in cracks and crevices. Most soft ticks like post-larval stages of *Argas reflexus* or *A. persicus* have a nocturnal feeding behaviour and during the day they remain hidden in the nest of their hosts.

Epidemiology. The vast majority of soft ticks are adapted to arid and semi-arid environments. Some species of genus *Argas* which are parasitic on domestic birds and feral pigeons have a wide distribution and can survive even very cold winters (Deplazes et al. 2016).

Argas reflexus and *A. persicus* can bite humans which come in contact with nests, mainly at night time.

Disease. *Argas reflexus* prefers to bite the body parts of pigeons with poor feather coverage (internal areas of the thighs, ventral part of the wings). The bite site becomes erythematous or even bluish and pigeons are restless during night-time. In competing pigeons, the flight performance is decreased. Heavy infestation leads to serious anaemia and even death can occur, mainly in nestlings or young birds. The parasitism by *Argas persicus* in domestic fowl is similar. Additionally, larvae of *A. persicus* can induce tick paralysis in chicken (Deplazes et al. 2016). Bites of *Argas reflexus* in humans can cause severe allergic reaction in humans.

Species in genus *Ornithodoros* are less pathogenic, but they have in turn an important vectorial role (see below).

The larvae and nymphs of *Otobius megnini* are parasites of the ear of horses and cattle in North America, Africa and parts of Asia. They have been reported also in Turkey.

Vectorial role. *Argas persicus* is the main vector of *Borrelia anserina* and *Aegyptianella pullorum*. *Argas reflexus* is a vector for *Aegyptianella pullorum*. *Ornithodoros moubata* is an important vector for the African swine fever virus and the relapsing fever spirochete, *Borrelia duttonii*.

Diagnosis. In *Argas*, only larvae are found for longer periods of time on the animals. Hence, for confirming the presence of nymphs and adults, nests of pigeons and poultry should be controlled carefully.

Treatment and control. Control of *Argas* in birds should target mainly the reduction of tick populations from the environment by applications of insecticides, during the day. Spraying must be done efficiently, in order to cover reach the crevices and other possible hideouts. The same principles are applied also for the control of other ticks.

2.2. Mesostigmatid mites

This group includes a great variety of mites, most of them free living (and predatory). Only few groups are parasitic. However, their veterinary importance is enormous, as they cause massive economic losses in poultry (*Dermanyssus*) or honeybee (*Varroa*) industry. The name of the group comes from the position of the stigmas which

are located at the level of the coxae of the second, third or fourth pair of legs, hence at mid-body. Unlike other parasitic mites, mesostigmatid mites can survive off-host, without feeding, for long periods of time (several months) (Wall and Shearer, 1997).

2.2.1. Red poultry mites (Dermanyssidae)

Red poultry mites (*Dermanyssus gallinae*) are common ectoparasites of birds, especially chicken with a worldwide distribution and important economic impact, often infecting also other animal hosts, including humans.

Taxonomy. There is one single species of veterinary importance, *Dermanyssus gallinae*, a cosmopolitan parasite of poultry, but which opportunistically attacks also mammals. Another species, *Liponyssoides sanguineus* is a common parasite of the house mouse and other synanthropic rodents (Deplazes et al. 2016). Both species can also accidentally feed on humans.

Morphology. The adults (figure 28) are very small, barely visible, between 0.7 x 0.4 mm (when unfed) and 1 mm long (when fully engorged) in length. When unfed, they have a pale, grey-white colour. When freshly fed, they become bright red and become darker as the blood is digested (Russell et al. 2013).

Biology and life-cycle. *Dermanyssus gallinae* is a nocturnal hematophagous ectoparasite of chicken. During the day, they usually hide in crevices and corners in the birds' habitat. When parasite

densities are high, mites can be found on chicken also during the day.



Figure 28. Female of *Dermanyssus gallinae* with an egg (photo Cristian Magdaş)

The life cycle is relatively rapid, and large populations can be founded rapidly under optimal conditions. The females lay eggs, from which the larvae hatch in 2-3 days. Larvae (figure 29) do not feed and moult in 1-2 days to the first nymphal stage (protonymph), followed after a blood meal by the second nymphal stage (trityonymph) and the adults. The females start laying the eggs after 12-24 hours following the first blood meal (Russell et al. 2013). A new generation can develop in as short as 7 days under optimal conditions (Deplazes et al. 2016). The hematophagous feeding of nymphs (figure 30) and adults take 30-90 minutes. Adults can survive up to 8 months without feeding.

Except domestic poultry, *D. gallinae* can feed on a great variety of other birds (pigeons, sparrows, starlings, captive parrots, etc.). It commonly attacks also

mammals (i.e. horses which live in close vicinity of chicken barns), as well as humans.



Figure 29. Larva of *Dermanyssus gallinae* (photo Cristian Magdaş)



Figure 30. Engorged nymph of *Dermanyssus gallinae* (photo Cristian Magdaş)

Epidemiology. This red poultry mite has a cosmopolitan distribution. It can be found in large populations in various breeding systems, from traditional backyard barns to intensive, industrial

farms. Temperatures under -20°C and above +45°C are deadly for the red poultry mites (Deplazes et al. 2016).

Disease. The bites of these mites are causing serious stress to birds, as they are painful and induce pruritus. Other symptoms include dermatitis, feather loss (figure 31), restlessness, anaemia (figure 32), reduced egg production, occasional mortalities (Deplazes et al. 2016) and also cannibalism (due to secondary skin injuries). Infested hen may leave the incubating eggs, causing low hatching rates (Russell et al. 2013).



Figure 31. Dermatitis and feather loss caused by *Dermanyssus gallinae*. Note the various stages of red-coloured mites (photo Cristian Magdaş)

The estimation of economic losses associated with *D. gallinae* can be as high as 11 million Euros per year in the Netherlands (Deplazes et al. 2016).

Horses can develop serious dermatitis, mainly on the head, if attacked by the poultry mites. In humans, the bites are itchy.



Figure 32. Anaemia caused by massive infestation with *Dermanyssus gallinae*. Note the various stages of red-coloured mites (photo Cristian Magdaş)

Diagnosis. For confirming the presence of *D. gallinae*, a close inspection of the habitat is recommended (figure 33), mainly in crevices, cracks, corners, under various object etc. Inspection of chicken during the night might reveal the presence of feeding nymphs and adults.



Figure 33. Massive numbers of *Dermanyssus gallinae* on the wall corners of a chicken barn (photo Cristian Magdaş)

Treatment and control. The major component for the control of red poultry mites should target the environment. Between technologic series (groups) of chicken, the empty stables should be cleaned thoroughly and sprayed with acaricides. Farms should be protected against the access of wild birds. There are few acaricides developed specifically for the control of *Dermanyssus* (Deplazes et al. 2016):

- **Phoxim** (2000 ppm, 2 times at 7 days interval, in the environment of birds, with special attention on the possible hiding places of the mites; avoid spraying the animals)
- **Spinosad** (approved as an organic product), applied as Phoxim
- **Other products:** pyrethroids, carbamates

2.2.2. Honeybee mites (Varroidae)

The varroosis of honeybees is a major veterinary problem worldwide, with a huge economic impact and one of the major causes for mortality of honeybee colonies.

Taxonomy. *Varroa destructor* is the most important species of the genus *Varroa*. Other species (i.e. *Varroa jacobsoni*) are of minor veterinary importance as they attack other bee species but not the honeybee, *Apis mellifera* (Deplazes et al. 2016).

Morphology. The most common stage found parasitic on honeybees are the females, which are 1.1-1.7 x 1.3-1.6 mm, flattened dorso-ventrally, transversely oval and brown in colour (figure 34).

They have four strong legs (Deplazes et al. 2016).



Figure 34. Microscopic details of a female *Varroa destructor* (photo Andrei D. Mihalca)

Biology and life-cycle. The parasitic stages feed by sucking haemolymph from the honeybees, using the chelicerae to penetrate through their body. Only females and the two nymphal stages feed. Males lack penetrating mouthparts. For mating, a female enters a brood cell, where it mates with the male. Following mating, the male dies, as the brood cell has been already capped by the bee colony. The female lays in the capped brood cell several eggs (up to six). Protonymphs (figure 35) (the first nymphal stage) hatch from these eggs, feed on the bee brood and develop into the second nymphal stage, the deutonymph. The deutonymph feeds also on haemolymph from the bee brood and develops into an adult. All stages leave the brood cell together with the hatching bees. The total duration of the

life cycle is around 7 days (Deplazes et al. 2016).



Figure 35. *Varroa destructor* nymph on the rim of a brood cell (photo Andrei D. Mihalca)

Epidemiology. Varroosis is the most debilitating bee disease worldwide and it is considered to be the major cause of mortality of honeybee colonies. The disease spread towards Europe from eastern Russia, in the 1960's and to other continents (South America, North America, Africa) in the 1970's. The transmission between the colonies takes through the contact between the male bees (drones) and worker bees, by robbing or swarming. Long distance spread take place by movement of bee colonies by beekeepers or by trade of queens or entire colonies (Deplazes et al. 2016).

Disease. The pathogenic effect of *V. destructor* is related to the intake of haemolymph from all stages of the bees, including larvae (figure 36), pupae (figure 37) and adults (figure 38). Bees originating from infected brood cells are

less developed than normal bees and have a shorter life. Heavy infestations may lead to malformed bees. The number of *Varroa* mites in a colony is gradually increasing from the spring to late summer. Massive infestation and lack of permanent control measures can commonly lead to the death of the colonies due to increased brood mortality (Deplazes et al. 2016).

Varroa destructor is also a suspected vector of several bee associated viruses.



Figure 36. *Varroa destructor* feeding on a honeybee larva (photo Andrei D. Mihalca)

Diagnosis. Low numbers of honeybees in a colony during the summer and the presence of malformed bees are indicative of varroosis. However, the infestation should be confirmed by demonstrating the presence of mites. They are visible also by the naked eye, but examination of bees under a stereo zoom microscope is helpful (Deplazes et al. 2016).



Figure 37 *Varroa destructor* feeding on a honeybee pupa (photo Andrei D. Mihalca)



Figure 38. *Varroa destructor* feeding on a honeybee adult (photo Andrei D. Mihalca)

Treatment and control. As varroosis is a notifiable disease, its control is usually part of the national strategic plans. The killing of mites using acaricidal drugs is difficult, as bees are also sensitive to such products. Examples of drugs which are registered for the control of

varroosis are: amitraz, flumethrin, coumaphos, thymol, tau-fluvalinate, oxalic acid dehydrate, lactic acid, formic acid etc. The methods of application are diverse. Some are in the form of plastic strips hung between brood combs, others are impregnated bands which release the drugs by evaporation etc.

2.2.3. Other mesostigmatid mites of veterinary importance

There are many other species of mesostigmatid mites which are parasitic on domestic animals or other animals of veterinary concern (exotic pets or laboratory animals).

Family Macronyssidae includes obligatory hematophagous parasites of mammals, birds and reptiles. There are few species of veterinary importance in this group. *Ornithonyssus sylviarum* is a common parasite of chicken, with almost worldwide distribution. Infestation can cause itching and feather loss. They should be differentiated from the red poultry mite, *D. gallinae*. *Ornithonyssus bacoti* (known also as the tropical rat mite) is a common parasite of various rodents but also of dogs, cats and birds, and occasionally even humans. In infested rodent colonies, the animals are restless and display itching. *Ophionyssus natricis* (figures 39-42) is a serious pest in exotic reptile colonies, causing mild to serious illness (disecdysis, anaemia) mainly in snakes but also in lizards. It is a vector for several viral diseases of snakes (Deplazes et al. 2016).



Figure 39. *Ophionyssus natricis*: engorged female (photo Andrei D. Mihalca)

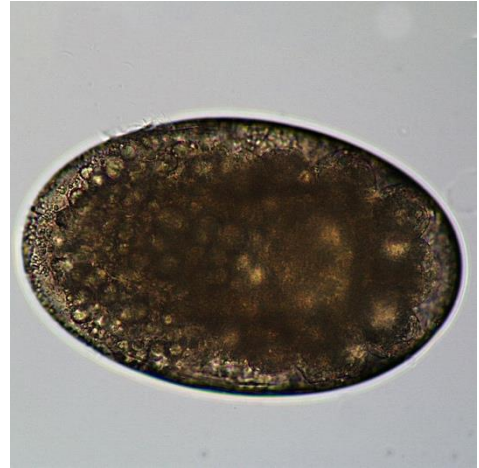


Figure 41. *Ophionyssus natricis*: egg (photo Andrei D. Mihalca)



Figure 40. *Ophionyssus natricis*: larva (photo Andrei D. Mihalca)



Figure 42. *Ophionyssus natricis* mite on a snake (photo Andrei D. Mihalca)

Family Halarachnidae includes various species of mites parasitic in the respiratory system or ear canal of mammals. Two species are of veterinary importance. *Pneumonyssoides caninum* are small mites (1-1.5 mm) parasitic in the nasal cavities and sinuses of dogs worldwide, with high prevalence mainly in Scandinavia.

Clinical signs are usually absent, and if present they are mild and consist of sneezing and nasal discharge. *Railletia auris* is a parasite of the ear canal of cattle, with almost worldwide distribution. The mites are located between the tympanum and a debris which results as a response to the local inflammation. The infestation is usually asymptomatic. If clinical are present,

they consist in head shaking or tilt (Deplazes et al. 2016).

Family Rhinonyssidae includes *Sternostoma tracheacolum*, a parasite of various species of birds, including caged canaries, finches and even budgerigars (Deplazes et al. 2016).

Family Laelaptidae comprises free-living and parasitic mites. There are several genera which are hematophagous parasites of rodents, including occasional cases on caged pet rodents. Another species, *Tropilaelaps clareae* is a mite parasitic on honey bees in Asia, with much smaller impact than *Varroa destructor*. It has not been reported to date in Europe (Deplazes et al. 2016).

2.3. Prostigmatid mites

Prostigmata includes a great variety of mite species, some of them, free-living, some others parasitic on plants or animals, including domestic species. The name of the group derives from the position of the stigmata which are usually opening in the anterior part of the body (on the *gnathostoma* or the anterior part of the *idiosoma*). Several families are included in this group, of which only few are of medical and veterinary importance. The most important prostigmatid mites are the species of *Demodex*, but other groups (i.e. fur mites, quill mites etc.) are also occasionally responsible for clinical signs in domestic animals (Wall and Shearer, 1997).

2.3.1. Demodicidae

The family includes several genera of parasitic mites of mammals. The most important genus is *Demodex*. They are parasitic in various mammal species, including humans and domestic animals. The most important species is *Demodex canis* which produces an important skin disease of dogs known as **demodicosis**.

Taxonomy. Genus *Demodex* includes several species, although the taxonomy of this group is still under debate. *Demodex canis* (figure 43) is the most important species and it is a parasite of dogs worldwide. Other species include: *D. equi* (in horses), *D. bovis* (in cattle), *D. ovis* (in sheep), *D. caprae* (in goats), *D. phylloides* (in pigs), *D. injai* (in dogs, but more rare than *D. canis*), *D. cati* and *D. gatoi* (in cats), *D. musculi* (in mice), *D. ratti* (in rats), *D. caviae* (in guinea pigs) (figure 44), *D. criceti* (in golden hamsters), and *D. folliculorum* (in humans) (Deplazes et al. 2016).

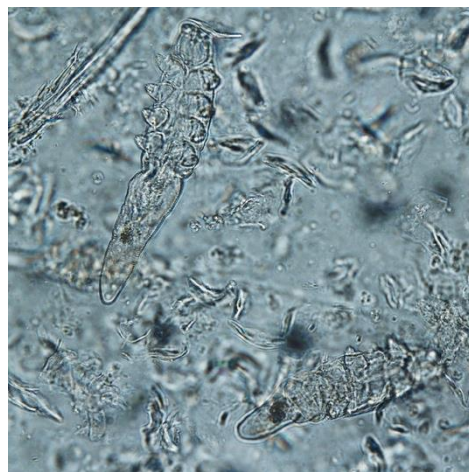


Figure 43. *D. canis* in a skin scraping from a domestic dog with demodicosis (photo Viorica Mircean)

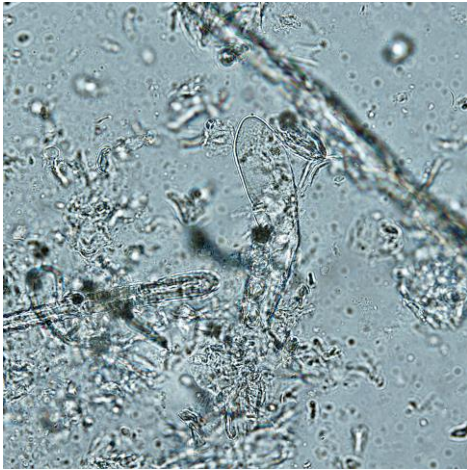


Figure 44. *D. caviae* in a skin scrapping from a guinea pig with demodicosis (photo Andrei D. Mihalca)

Morphology. Members of genus *Demodex* are small mites with a worm-like shape. Their size varies from 250 to 300 μm in length and 40 μm in width. The legs are very short and are located in the anterior half of the body (figure 43). The body surface is striated. The mouthparts are also very short and stout. In some host, shorter forms are sometimes found. However, it is not known if such forms are different species or intraspecific variations of the typical species (Russell et al. 2013; Deplazes et al. 2016).

Biology and life-cycle. It is general accepted that species of *Demodex* are host specific, and interspecific transmission has never been demonstrated. The mites live in the hair follicles, sebaceous glands and Meibomian glands of the dermis in a head-down position. The copulation between males and females usually occurs at the skin surface, in the pores.



Figure 45. Egg of *D. canis* in a skin scrapping from a domestic dog with demodicosis (photo Viorica Mircean)

Adults have a very short life span of only 3-5 days. After copulation, females move back to the hair follicles or to the glands where they lay around 20 eggs. The eggs have a typical lemon shape (figure 45) and measure 70-90 x 19-25 μm . Each egg will produce a hexapod larva which moults into a second larval stage, also hexapod, which is sometime designated as a protonymph. Another moulting will produce the next stage, known as deutonymph. The final moulting will produce the adults (Russell et al. 2013; Deplazes et al. 2016). The complete life cycle takes 2-3 weeks.

Epidemiology. The most commonly affected domestic species are dogs, goats and pigs (including wild boars). In cattle and horses the disease is rare and in cats it is exceptional (Russell et al. 2013). However, the presence of *Demodex* mites is more common than the clinical disease, as they are considered to be commensals of the skin. In dogs the prevalence can be as high as 85%, but

clinical signs are less common. Nevertheless, demodicosis is included in the top 10 most common dermatological conditions of dogs (Russell et al. 2013; Deplazes et al. 2016). The disease is not uncommon in exotic small mammals, especially in hamsters and guinea pigs.

The mites cannot survive off-host, hence horizontal transmission is not possible. The main route of skin colonization occurs in the post-partum period and is favoured by several factors such as the close and prolonged contact between the mother and offspring, warmth and humidity during suckling, hormonal status of females and the immature immune system of the babies (Deplazes et al. 2016). In dogs the infestation by *D. canis* take place in the first 2-3 days of life (Russell et al. 2013). Young dogs are more affected than adults and certain breeds are more sensitive than others (Deplazes et al. 2016).

Disease. The lesions are produced when high number of mites multiply in the hair follicles and destroy the hair shaft, followed by hair loss (clinically corresponding to alopecia). Mites can move from the hair follicles to the sebaceous glands where they destroy the keratinocytes. Prolonged irritation induces hyperplasia, followed by hyperkeratosis and dyskeratosis. Often, such lesions are colonized by bacteria which are responsible for pustule formation (Deplazes et al. 2016).

A genetic predisposition has been described in certain dogs (as often multiple cases occur in littermates), but the exact genes involved are not known. The severe, generalized forms are

typically associated with an overexpression of MHC (type II) in the skin. Immunosuppression of other causes is also associated with more severe forms of disease. The infection becomes clinical also after certain treatments (corticoids, cytotoxic drugs) or as a result of concurrent diseases (neoplasms, canine distemper) or stress (oestrus, pregnancy, malnutrition) (Deplazes et al. 2016).

As mentioned before, most infections are asymptomatic, as *Demodex* lives a commensalistic life.

In dogs, when symptoms are present, the demodicosis has two distinct clinical forms: the squamous forms and the pustular forms. The **squamous form** is characterized by scaly eczema, cutaneous erythema, alopecia (figure 46), and hyperkeratosis. It is usually localized on the head (forehead, periocular, ears, around the lips, around the nose) and more rarely found on the trunk and legs.



Figure 46. Focal alopecia in a dog with demodicosis (photo Viorica Mircean)

The **pustular form** (figures 47-49) is more severe and can be localized or generalized. It is usually a complication of the first form, caused by secondary bacterial infections. Pustules (suppurative folliculitis) are a common finding. Usually the pruritus is absent in demodicosis, but the pustular form can be painful. Severe forms can be followed by sepsis, lymphadenopathy, anorexia, or lethargy (Deplazes et al. 2016).



Figure 47. Generalised demodicosis in a Pug: ulceration and facial crust (photo Viorica Mircean)

Except these two forms also atypical forms of demodicosis are known in dogs: the **alopecic form** (alopecia is the single change and it is localized mainly on the head), **pododemodicosis** (figure 50-51) (pustules on all four paws) or **otodemodicosis** (otitis of the external ear) (Deplazes et al. 2016). The squamous form is common mostly in young dogs (less than one year old) and about 90% of the cases resolve in 1-2 months without treatment. The other 10% become progressive. The pustular form is more common in dogs over the

1.5 years old, up to four years old (Deplazes et al. 2016).



Figure 48. Generalised demodicosis in a mixed-breed: ulceration and facial crust (photo Viorica Mircean)



Figure 49. Generalised demodicosis in a mixed-breed: ulceration and facial crust (photo Viorica Mircean)

In pigs, the lesions are localized mainly on the face, sometimes extending on the ventral part of the neck, thoracic region or even belly. **In cattle and goats**, the lesions are more common on the brisket, lower neck, forearm, shoulder, and

dorsally behind the withers. The pustular form can become severe in pigs and goats, as large abscesses can form (Russell et al. 2013).



Figure 50. Pododemodicosis in a West Highland White terrier: alopecia, erythematous swellings and onychogryphosis (photo Viorica Mircean)



Figure 51. Pododemodicosis in a mixed-breed: alopecia, erythematous swellings, fistulae and sanguineous pus (photo Viorica Mircean)

In horses, demodicosis is rare. Lesions have been described mainly on the head, neck and front legs. **In cats**, the disease

is extremely rare and somehow similar to dogs (Deplazes et al. 2016). In guinea pigs and hamsters demodicosis causes usually squamous dermatitis (figure 52).



Figure 52. Squamous dermatitis caused by *D. criceti* on the back of a golden hamster (photo Andrei D. Mihalca)

Diagnosis. The diagnostic should rely always on the visualisation of mites (any stage, including the typical lemon-shaped eggs) under the microscope. A skin scrapping is recommended from the lesions.

For an increased sensitivity, a skin fold should be squeezed until the contents is leaking. This should be scrapped firmly, until capillary bleeding occurs. The collected scrapping is a put on a microscope slide, mixed with KOH or lactophenol for clarification, covered with a cover slide and examined under a microscope. It is recommended to perform several scrapping from the same site and also to check scrapping from multiple sites, where lesions occur (Deplazes et al. 2016). Presence of mites

has a clinical diagnostic value only if dermatological lesions are present. Sometimes, the mites are absent in the skin scraping but visible at the histological examination of cutaneous biopsies (Deplazes et al. 2016).

In heavy infestations, due to skin licking, mites can be found also in the feces of the dogs.

Treatment and control. In young dogs with localized squamous forms of demodicosis, treatment with acaricides is not recommended, as symptoms usually resolve spontaneously in 1-2 months. Generalized forms and pustular forms require medical attention. The specific treatment with acaricides is usually done with 0.5‰ amitraz solution by full body wash or dips, repeated every 5-7 days until clinical cure and continued for two month after the scraping is negative. As amitraz has a certain level of toxicity, dogs with severe skin lesions should be treated with 0.25‰ amitraz. Generalized demodicosis can be treated with a success of up to 80% (Deplazes et al. 2016).

Except amitraz, also other commercial treatments are approved for demodicosis. These include: moxidectin + imidacloprid 2.5 mg/kg + 10 mg/kg spot-on (2-4 treatments at 1 month interval); amitraz + metaflumizone 20 mg/kg + 20 mg/kg spot-on (at one month interval) (Deplazes et al. 2016).

In pustular forms, antibiotics and vitamin supplements are recommended.

2.3.2. Fur and quill mites

Fur and quill mites are mites living on the hair of mammals or on the feather of birds, sometimes with clinical dermatological signs, other times with asymptomatic outcome.

Taxonomy. Family Cheyletiellidae (fur mites) includes several genera, many of them free-living. Nine genera have parasitic representatives. The most important genus is *Cheyletiella*. There are three species of veterinary importance: *C. yasguri* (in dogs), *C. blakei* (in cats) and *C. parasitivorax* (in rabbits) (Russell et al. 2013).

Family Syringophilidae (quill mites) includes several genera parasitic on the quills of the feathers on the wing and tail of wild and domestic birds worldwide. Genus *Syringophilus* includes species parasitic on the feathers of chicken (*S. bipectinatus*), pigeons (*S. columbae*) but also other species in turkey, pheasants, canaries, etc. (Deplazes et al. 2016).

Morphology. Species of *Cheyletiella* are relatively large mites (~350 µm in length), with strong, stiletiform chelicerae, used to pierce the skin of the host (Russell et al. 2013).

Biology and life-cycle. *Cheyletiella* are obligatory parasites and live on the keratin layer of the epidermis. Sometimes, they pierce the skin and feed with the tissue fluids of their host. All the development takes place on the host. The females lay eggs (230 x 100 µm) and attach them to the hair, 2-3 mm above the skin surface. There is one larval stage, two nymphal stages and the adults. Females can survive off-host for

ca. 10 days. The complete life cycle takes 3 weeks. Fur mites are very mobile and move quickly, hence the name “walking dandruff” (Russell et al. 2013).

Epidemiology. The fur mites are relatively common in domestic rabbits, with prevalence of up to 70% in certain areas. In dogs and cats they are more rare (Deplazes et al. 2016). Transmission from a host to another is via direct contact but fur mites have been found on fleas and louse flies, suggesting a phoretic transmission (Russell et al. 2013).

Disease. The main clinical signs in dogs and cats is mild to severe dandruff, chronic eczema, pruritus. The principal locations of the lesions are the head, shoulder and back. In cats, military dermatitis can develop. The severity of lesions is correlated with the number of mites. Hence, in cats, due to constant grooming and consequent removal of mites and their eggs, the level of infestation and frequency of clinical signs are lower than in dogs (Deplazes et al. 2016). In rabbits, the preferred location of the fur mites is in the scapular region. Rarely, humans can be also infested with *Cheyletiella* from dogs and cats. Skin reactions in humans are possible under the form of itching, erythematous macules and papules mainly on the arms and upper body (Russell et al. 2013; Deplazes et al. 2016).

Quill mites infestation in birds is usually asymptomatic. Massive numbers of mites can induce some feather loss (Deplazes et al. 2016).

Diagnosis. The best way for fur mite detection is the use of the scotch tape method or a vacuum cleaner (Deplazes et al. 2016).

Treatment and control. Fipronil spot-on or selamectin spot-on have been used successfully for the treatment of fur mites in dogs and cats (Deplazes et al. 2016).

2.3.3. Other prostigmatid mites of veterinary importance

There are several other groups of prostigmatid mites which are parasitic on domestic animals or other animals of veterinary concern (exotic pets or laboratory animals).

Family Trombiculidae. This is a very diverse family of mites (with more than 1200 species) in which only larval stages are parasitic (figure 53), while the nymphs and adults are free-living (mostly predatory on the eggs and immatures of other arthropods) (figure 54). At least 50 species were found on domestic animals and/or humans. Typically, they have a brick-orange colour (Deplazes et al. 2016).

The most important species in which the larvae are parasitic on domestic hosts are: *Neotrombicula autumnalis* (in Europe), *Neotrombicula alfreddugesi* (in the Americas) and *Eutrombicula sarcina* (in Asia and Australia). The larvae attach to the host can cause skin reactions: moderate to extreme itching, localized erythema, crusting and blisters. Some species are vectors of *Rickettsia* (Russell et al. 2013; Deplazes et al. 2016).



Figure 53. Trombiculid larvae parasitic on a lizard (photo Andrei D. Mihalca)



Figure 54. Free living adult trombiculid (photo Andrei D. Mihalca)

Family Psorergatidae. *Psorergates ovis* is causing skin disorders in sheep from New Zealand, Australia, South Africa and South America. Symptoms of infestation can be absent but also alopecia, scaly dermatitis and skin thickening have been described. It affects mainly merino sheep (Russell et al. 2013; Deplazes et al. 2016). *Psorergates bos* is another

species, parasitic on cattle in USA (Russell et al. 2013).

Family Myobiidae. The family has a worldwide distribution with representatives parasitic on various mammals (marsupials, bats, rodents, insectivores). Two species have veterinary importance, as they parasitize laboratory mammals: *Myobia musculi* (in house mice) and *Radfordia ensifera* (in laboratory rats). The mites are very small and feed on tissue fluids and blood. In massive infestation they cause cutaneous lesions (dermatitis, alopecia, itching) (Russell et al. 2013; Deplazes et al. 2016).

Family Tarsonemidae. The family includes several genera of which the most important is *Acarapis*, with a number of species parasitic in the trachea of bees. *Acarapis woodi* is found in the trachea of the European honeybee (*Apis mellifera*). This mite is spread worldwide and is common in many European countries. The affected bees display restlessness, abnormal wing positions, weakness and death as a results of hemolymph loss through the tracheal lesions (Deplazes et al. 2016).

2.4. Astigmatid mites

Astigmata is relatively diverse group of parasitic mites, generally small in size. As their name suggests, they lack stigmas are absent and their respiration takes place directly through the cuticle. There are several families in this group, of which Psoroptidae, Sarcoptidae and Knemidocoptidae are of medical and

veterinary importance (Wall and Shearer, 1997).

2.4.1. Psoroptid mange mites

Taxonomy. There are three genera parasitic in domestic animals *Psoroptes*, *Chorioptes* and *Otodectes* (table 3).

Morphology. Members of Psoroptidae family are oval mites. From above, the third and the fourth pair of legs are visible (Russell et al. 2013).

Mites of genus *Psoroptes* are oval (figure 55), ca. 560-820 μm (females) and 380-570 μm (males). The main morphological feature of the genus based on which it can be differentiated from other psoroptids is the presence of small, sucker-like, trumpet-shaped pulvilli (figure 56). The gnathostoma is long and pointed (Russell et al. 2013; Deplazes et al. 2016).



Figure 55. *Psoroptes cuniculi*: general aspect of the body (photo Andrei D. Mihalca)

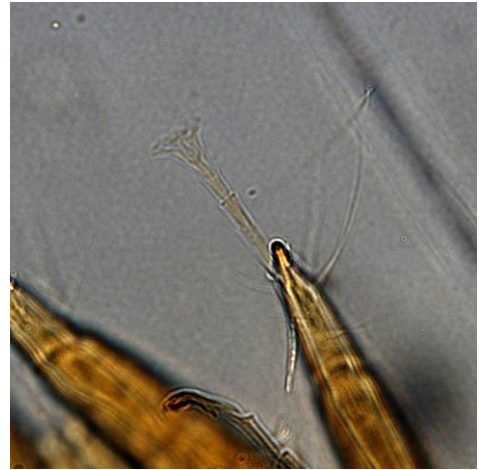


Figure 56. *Psoroptes ovis*: details with a trumpet-like pulvillus (photo Andrei D. Mihalca)

Mites of genus *Chorioptes* (figure 57) are smaller than *Psoroptes* (females: 400-600 μm , males: 300-450 μm). The gnathostoma is elongated, but also wider than in *Psoroptes*. The sucker-like pulvilli on the pretarsus is larger than in *Psoroptes* and cup-shaped (figure 58) (Russell et al. 2013; Deplazes et al. 2016).



Figure 57. *Chorioptes bovis*: general aspect of the body (photo Andrei D. Mihalca)



Figure 58. *Chorioptes bovis*: details with a cup-shaped pulvillus (photo Andrei D. Mihalca)

Otodectes cynotis (figure 59) (females: 350-500 μm , males: 275-360 μm) and otherwise resemble *Psoroptes* but their pretarsus is unjointed (Russell et al. 2013; Deplazes et al. 2016).



Figure 59. *Otodectes cynotis*: general aspect of the body (photo Andrei D. Mihalca)

Biology and life-cycle. Psoroptid mites are generally non-burrowing mites, living on the skin of various mammals.

The life cycle of all species includes two nymphal stages. The life cycle of all species takes place entirely on the host (Russell et al. 2013). Females of *Psoroptes* live on the skin of their host and have a life span of about 11-42 days. After mating, they lay in this time course 30-80 large eggs from which the larvae hatch in ca. 10 days. The larvae are followed by a protonymph and later by a tritonymph which will moult to adults. The entire life cycle takes around 21 days. All stages feed with tissue fluids, skin exudate or even blood (Deplazes et al. 2016). The life-cycle of *Chorioptes* follows more or less a similar pattern as in the case of *Psoroptes*. The mites live at the skin surface where they feed on epidermal cells, sebum and skin exudate (Deplazes et al. 2016). The life cycle of *O. cynotis* is completed in 3 weeks. The life span of the females is almost two months. All stages feed with the exudate and debris from the external ear canal (Deplazes et al. 2016).

Epidemiology. Transmission of all psoroptid mites is usually by direct contact. However, they can survive off-host for variable times (2-3 weeks for *Psoroptes*; 3-10 weeks for *Chorioptes*; several months for *Otodectes*) (Deplazes et al. 2016). Psoroptic mange is the most common mange in sheep. Outbreaks can spread fast, as the disease is highly contagious. There is no breed predisposition in sheep, but lambs are more commonly affected. In goats, the breeds with longer hair are more susceptible. The ear mange caused by *P. cuniculi* is the most common form of mange in rabbits (Deplazes et al. 2016).

Table 3. Psoroptidae parasitic in domestic animals (after Deplazes et al. 2016)

Species	Host	Location of the lesions (mange)
<i>Psoroptes ovis</i>	sheep	body
	cattle	body
	equids	body
	camels	body
<i>Psoroptes cuniculi</i> ¹	rabbits	ear
	goats	ear
	sheep	ear
	horse	ear
<i>Psoroptes natalensis</i>	water buffalo	body
	cattle	body
	horses	body
<i>Chorioptes bovis</i>	cattle	tail
	goat	back
	sheep	foot
	horse	foot
<i>Chorioptes texanus</i>	cattle	tail, foot
<i>Otodectes cynotis</i>	dog	ear
	cat	ear

1 - considered by some authors a synonym of *P. ovis*

Chorioptic mange is the most common form of mange in cattle and horses and also common in South American camelids (llamas and alpacas) (Russell et al. 2013). In temperate areas, the prevalence is generally higher during the stabling and lower during the grazing season. High humidity and temperature are considered risk factors (Deplazes et al. 2016).

The hosts of *O. cynotis* are dogs, foxes, cats, and ferrets. The prevalence of otodectic mange is domestic cats in Europe was found to be (average) 17%. A very high prevalence is recorded in red and arctic foxes (up to 100%), while in dogs is more are (up to 3%) (Russell et al. 2013; Deplazes et al. 2016).

Disease. The psoroptid mites are responsible for different clinical signs, depending on the mite species and on the host species. In general, the pathogenesis of mange caused by psoroptid mites is related to local

hypersensitivity (type I) reaction. Histologically, the lesions appear as exudative dermatitis, oedema, infiltration with eosinophils, plasma cells, and mastocytes. Subsequent pruritus is mechanically aggravating the lesions. Other skin lesions develop after the initial hypersensitivity reactions: acanthosis, spongiosis, parakeratosis, alopecia, erythema, scales, and crusts. Repeated infestation can lead to partial immunity, with less severe lesions at re-infestation. Often, the lesions are complicated by bacterial secondary infections. Leather damage is common and important from economic point of view (Deplazes et al. 2016).

In horses. The **psoroptic mange** produced by *P. ovis* affects mainly the areas with long hair (mane base, tail) (figure 60) but in time the lesions can extend to the back, shoulder or croup. Horses can be infected rarely also with *P. cuniculi* causing ear mange.



Figure 60. Psoroptic mange at the mane base in a horse (photo Andrei D. Mihalca)



Figure 61. Chorioptic mange in the area of the fetlock in a horse (photo Cristian Magdaş)

The **chorioptic mange** caused by *C. bovis* is the most common mange in horses. It affects typically the feet, with lesions at the level of the fetlock, commonly in both hind legs (figure 61), rarely in front legs. Horses are rubbing the legs to hard objects as the pruritus is intense. Crusts are the typical cutaneous lesions. Usually horses from heavy draft breeds, which have longer hair at the level of fetlocks are more commonly affected (Deplazes et al. 2016).

In cattle. The **psoroptic mange** produced by *P. ovis* affects primarily the areas with dense hair (figure 62) and is known as body mange. The initial clinical signs consist of crusts and papules, with severe itching, leading to pruritus and detachment of crusts. The lesions are predominantly located on the withers, neck, tail, back and flanks. If untreated, the cutaneous lesions can generalize. Chronic persistence of lesions leads to weight loss and decreased milk production due to stress and permanent movement.



Figure 62. Psoroptic mange in the area of the back in a water buffalo (photo Cristian Magdaş)

Death can occur if large surfaces of skin are affected. Other lesions associated with the psoroptic mange in cattle include lymph node enlargement and hyperplasia of the adrenal glands (as a response to stress). The **chorioptic mange** of cattle caused by *C. bovis* is responsible for tail lesions (tail mange). Itchy crusts and hair loss occur at the base of the tail (figure 63), perineal

region, inner areas of the hind legs and even udder. Due to pruritus and restlessness, the production is significantly affected (Deplazes et al. 2016).



Figure 63. Chorioptic mange in the area of the tail in a cow (photo Cristian Magdaş)

In sheep. The **psoroptic mange** produced by *P. ovis* is the most common form of mange in sheep. The lesions are similar to those described in cattle (pustules, crusts), with severe itching. Large pieces of wool are detaching (figure 64) leaving an inflamed, thickened and wrinkled skin. The lesions are predominantly located on the neck, shoulders, back, and flanks but they often become generalized. Sheep can be infected rarely also with *P. cuniculi* causing ear mange. The **chorioptic mange** caused by *C. bovis* in sheep is associated with hind-leg lesions (dew claws, fetlock) or, in rams, on the scrotum. Typically, the chorioptic mange in sheep is mild (Deplazes et al. 2016).



Figure 64. Psoroptic mange in the area of the back in a sheep (photo Cristian Magdaş)

In goats. The **psoroptic mange** produced by *P. cuniculi* causes ear lesions, typically located on the ear pinna and ear base. In long haired breeds, other parts of the body can be affected (Deplazes et al. 2016).

In dogs and cats. The only psoroptid affecting companion animals is *O. cynotis*, causing the **otodectic mange**. Clinical signs are of external otitis with the formation of crusts in the external ear canal (figure 65). Presence of pruritus is common, but usually not as intense, or even absent in cats. Although the disease is more rare in dogs than in cats, the pruritus in the former is more common and more intense. In chronic infestations, the lesions may spread to the head or even to the body, but this is a rare event. Secondary bacterial infections are not uncommon and require more complex therapy (Deplazes et al. 2016).



Figure 65. Otodectic mange in a cat: crusty otitis externa (photo Andrei D. Mihalca)

In rabbits. The **psoroptic mange** produced by *P. cuniculi* affects typically the ears, with formation of abundant crusts in the ear canal (figure 66), associated with pruritus (Deplazes et al. 2016).



Figure 66. Psoroptic mange in a rabbit: crusty otitis externa (photo Andrei D. Mihalca)

Diagnosis. For confirmation of the etiologic agent, the presence of the mites should be confirmed in the lesions. This can be done by performing a skin

scraping, using a scalpel blade followed by clarification with KOH or lactophenol and examination under the microscope. Sometimes the presence of mites can be demonstrated by examining the crusts under a zoom stereomicroscope (figure 67). The presence of mite eggs (figure 68) also has a diagnostic value.



Figure 67. *Psoroptes ovis* collected from a water buffalo viewed under a zoom stereomicroscope (photo Cristian Magdas)

Treatment and control. For the treatment of **psoroptic mange in sheep**, dipping with acaricides is recommended. There are several options: **phoxim** (500 mg/l), **diazinon** (200-500 ppm) or **flumethrin** (30 ppm). Dipping is recommended in the autumn, until the weather is not cold. During dipping, attention should be paid that all body parts, including the ear canal are immersed. The head must be submerged at least once, and the whole body for at least 1 minute. The dipping solution must be freshly prepared and the wool length should be minimal.

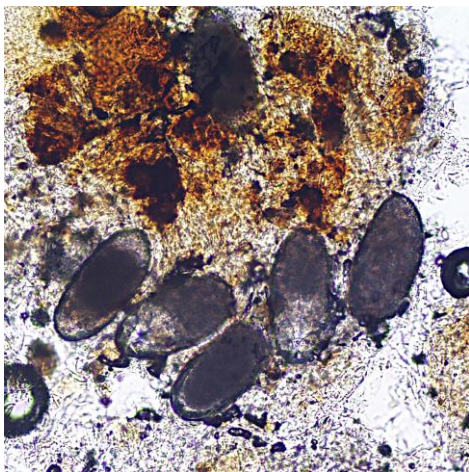


Figure 67. Eggs of *Otodectes cynotis* collected from the ear of a naturally infected domestic cat (photo Andrei D. Mihalca)

The psoroptic mange in sheep can be treated also with systemic drugs like the macrocyclic lactones: **doramectin** (0.2-0.3 mg/kg, single dose), **ivermectin** (0.2 mg/kg, repeated after 7 days), or **moxidectin** (0.2 mg/kg, repeated after 7 days). Pour-on formulations are less effective against mange in sheep. The same protocol can be used for the treatment against *Chorioptes* in sheep.

In cattle, mange caused by psoroptid mites can be treated with **dipping or spraying**. The following products can be used: **organophosphates** (coumaphos, chlorfenvinphos, chlorpyrifos, diazinon), **formamidines** (amitraz) or **pyrethroids** (deltamethrin, flumethrin, cypermethrin). **Pour-on** products are also efficient against mange mites in cattle: pyrethroids (deltamethrin, flumethrin, cypermethrin), macrocyclic lactones (doramectin, eprinomectin, ivermectin, moxidectin). **Injectable** macrocyclic lactones (doramectin, ivermectin, moxidectin) are also available for cattle.

In horses, **spraying** and **dusting** are the most commonly used methods for the treatment against psoroptid mites. Formulations based on **organophosphates** (chlorfenvinphos, coumaphos, diazinon) and **pyrethroids** (cypermethrin, deltamethrin, permethrin) are commercially available. **Pour-on** products based on pyrethroids are also available for horses. Oral formulations with macrocyclic lactones are less effective.

In rabbits, psoroptic mange can be treated with **injectable macrocyclic lactones** (ivermectin), once weekly, for four weeks. **Topical** formulations based on **selamectin**. **Oral moxidectin** is also efficient. However, most of these products are not officially registered for rabbits and should be used off-label, with caution.

The treatment of **otodectic mange in dogs and cats** can be achieved with various products. Commercially, the following combinations are registered for the treatment of otodectic mange: **imidacloprid + moxidectin** (spot-on in cats), **amitraz + fipronil + methoprene** (spot-on in dogs), **selamectin** (spot-on, for dogs and cats), **sarolaner** (oral, for dogs). **Ear drops** with pyrethrins, ivermectin or milbemycin oxime are also used.

2.4.2. Sarcoptid mange mites

Sarcoptids, also known as burrowing mites are mites which live in the epidermis, where they dig tunnels and cause severe skin inflammation in a wide range of domestic and wild animal

species, as well as in humans (zoonotic transmission).

Taxonomy. There are three genera of medical and veterinary importance. Genus *Sarcoptes*, with a single species, *S. scabiei*, is responsible for the sarcoptic mange of all domestic mammals and of scabies in humans. Genetically, it has been demonstrated that there are various genotypes (known as varieties), preferentially associated with various hosts: *S. scabiei* var. “bovis” (in cattle), var. “equi” (in horses), var. “ovis” (in sheep), var. “rupicaprae” (in goats and chamois), var. “cameli” (in camels), var. “suis” (in pigs), var. “canis” (in dogs), var. “vulpes”, var. “cuniculi” (in rabbits), var. “hominis” (in primates). They are not distinguishable morphologically (Deplazes et al. 2016; Arlian and Morgan 2017).

Genus *Notoedres* includes 45 species. The most important are *N. cati* (in cats and other carnivores, in rabbits), *N. musculi* (in house mice and other Muridae), and *N. muris* (in various rodents).

Genus *Trixacarus* includes 3 species. *T. caviae* (in guinea pigs), *T. diversus* (in rats from Europe) and *T. eliuris* (in rodents from Africa) (Bochkov 2010).

Morphology. *Sarcoptes scabiei* has an oval appearance, with a ventrally flat and dorsally convex body (figure 68). On the dorsal part, many cuticular spines are present. They have short, stubby legs. Adult stages are small (females 300-500 µm, males 200-300 µm). The gnathosoma is short (Deplazes et al. 2016; Arlian and Morgan 2017).

Mites of genus *Trixacarus* (figure 69) have a very similar morphology with *Sarcoptes* and can be easily confused. The anus is in dorsal position. As regards mites of genus *Notoedres* (figure 70), they also have a very similar morphology to *Sarcoptes*, but they are slightly smaller (females 200-240 µm, males 150 µm) and have the anus in dorsal position (Bochkov 2010).



Figure 68. Adult *Sarcoptes scabiei* (photo Andrei D. Mihalca)

Biology and life-cycle. The mating of *Sarcoptes scabiei* occurs at the skin surface. After copulation, the males die. Inseminated females dig galleries (up to 1 cm in length, equal to 20 times their body size) in the epidermis. They feed with the tissues (cytoplasm of the epidermic cells). Each tunnel has only one female which lays 1-3 eggs per day, for two months. A hexapod larva hatches from each egg after few days. The larvae pass through two nymphal stages (protonymph and tritonymph) and later become adults. The complete development from egg to adults takes 2-3 weeks (Deplazes et al. 2016).



Figure 69. Adult *Trixacarus caviae* (photo Andrei D. Mihalca)



Figure 70. Adult *Notoedres* sp. from a laboratory rat (photo Cristina Ștefănuț)

If they are dislodged from the host, they can survive in the environment for several days or even weeks if the conditions are suitable. They even display a host-seeking behaviour and actively move towards the host being attracted probably by the odour, heat and/or CO₂ (Arlian and Morgan 2017).

The life cycle of *Notoedres cati* is similar to the one described for *S. scabiei*.

Epidemiology. All species of veterinary importance have a worldwide distribution. The transmission is usually by direct contact between infected and non-infected animals. In Europe, sarcoptic mange is common in pigs, wild carnivores (mainly foxes), and dogs. It is relatively rare in ruminants (Deplazes et al. 2016).

Notoedres cati affects domestic and wild felids worldwide. The notoedric mange of domestic cats is rare in Europe.

Interspecific transmission is rare, although some varieties are known to cross the species border. This has been experimentally demonstrated between dogs and foxes, dogs and rabbits, chamois and domestic goats, racoons and foxes but also between different carnivores and their prey, suggesting that under natural conditions, this might be an important route of infection (Arlian and Morgan 2017). Some animal varieties are also infective to humans, hence, sarcoptic mange is considered to be zoonotic.

Disease. Sarcoptic mange usually affects the body parts with short and/or sparse hair. The incubation period is 2-3 weeks. The most common signs include intense pruritus, erythema, papulae, vesiculae, crusting, hyperkeratosis and alopecia. Secondary bacterial infections are common. If left untreated, the skin lesions become generalized and will severely affect the overall metabolism of the host and can lead to death. Chronic, long-term evolving sarcoptic mange has been associated with stress, weight loss, decreased productions etc. (Deplazes et al. 2016). The pathogenesis of sarcoptic

mange is considered to be immune-mediated. When burrows are initially dug by females, the host reacts by hyperproduction of keratin, to seal them. In response, the mites produce saliva with keratolytic effect. However, the saliva also contains antigenic compounds, which, together with the antigens from the body components, faeces, or eggs will induce a type IV, followed by a type I allergic reaction. This phase is known as the hyperergic phase. After several 4-5 months, some animals can desensitise and clinical signs may recede (Deplazes et al. 2016).



Figure 71. Sarcoptic mange in a calf. Note the crusty lesions in the dorsal area (photo Andrei D. Mihalca)

Signs may slightly vary from host species to host species. **In horses**, the disease is very rare, and the occasional cases reported from time to time in Europe are associated probably with the fox variant. **In cattle**, the lesions are typically located on the head and neck, the shoulders, udder, tail, and back (figure 71).

In sheep and goats, *Sarcoptes* causes the head mange. **In pigs**, lesions are located most commonly on the internal part of the ear pinna, behind the ear, nose, neck and back. The lesions are highly hyperkeratotic. **In dogs**, the lesions are located on the head (figure 72) but frequently spread to other areas (chest, abdomen, legs) and can become generalized. **In cats** the sarcoptic mange is rare.



Figure 72. Sarcoptic mange in a puppy. Note the crusty lesions on the head (photo Andrei D. Mihalca)

In small pet mammals the sarcoptic mange has been reported occasionally in rabbits, mice, hamsters and hedgehogs.

In wild animals, the sarcoptic mange has a serious impact mainly in foxes (figure 73), other carnivores (figure 74) and ruminants (chamois, ibex, cervids).

In humans (figure 75), scabies is usually starting on the arms as small papules which are very itchy. The disease can also extend and even become generalized if untreated.



Figure 73. Sarcoptic mange in a red fox from Romania (photo Andrei D. Mihalca)



Figure 74. Sarcoptic mange in a racoon dog from Romania (photo Botond J. Kiss)

The **notoedric mange** affects mainly domestic cats and rabbits and has a similar pathogenesis.

In domestic cats, the main affected area is the head (edge of ears, forehead), with severe pruritus. The lesions (small papules, crusts) can also spread to other body areas, mainly the neck. If left untreated, the disease can progress to

severe weight loss and death, mainly in young cats (Deplazes et al. 2016).



Figure 75. Early lesions of scabies in a human patient (photo Andrei D. Mihalca)

In wild felids, the disease has been associated with important mortalities in bob cats, both in USA and Europe.

In rabbits, *Notoedres* causes lesions around the main orifices of the body.

The **trixacarinic mange** caused by *T. caviae* is a relatively common dermatologic problem in pet guinea pigs (figures 76-77). The clinical appearance is similar to the sarcoptic mange, with lesions occurring mainly in the dorsal part of the body.

Diagnosis. As mites are located in the deep layers of the epidermis, a profound scrapping is recommended from the peripheral areas of the lesions, preferably over a total area of several square cm. The scrapping should be done until capillary bleeding occurs.

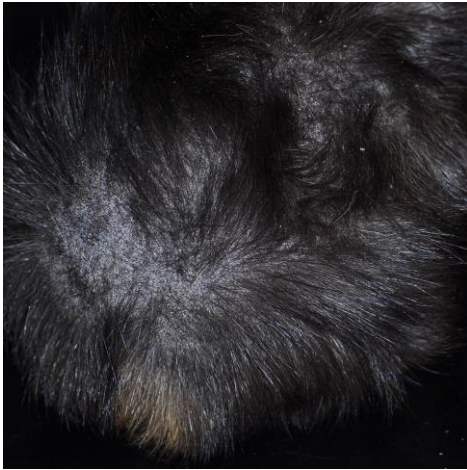


Figure 76. Trixacaric mange in a pet guinea pig. Note the fine crusty dermatitis in the dorsal area (photo Andrei D. Mihalca)



Figure 76. Trixacaric mange in a pet Siberian chipmunk (photo Andrei D. Mihalca)

As the sensitivity of the method in chronic cases is low (only few mites are present at the level of the lesions), repeated scraping are recommended. The scrapping should be cleared with KOH or lactophenol and examined under the microscope.

Treatment and control. In livestock and horses, the treatment of sarcoptic mange follows the same protocol as for the psoroptic mange (see chapter 2.4.1). In dogs and cats, the same products (with the exception of ear drops) as those mentioned for the treatment of the ear mange are available (see chapter 2.4.1). In pet rodents, the best results are achieved with injectable ivermectin (0.4 mg/kg), three doses, every 10 days. Other macrocyclic lactones are also efficient (i.e. injectable doramectin, topical selamectin). However, none of these products are officially registered for use in guinea pigs or other rodents. Their off-label use must follow the consent of the owner.

2.4.3. Knemidocoptid mange mites

Knemidocoptid mange mites are ectoparasites of birds, causing mange-like lesions at various sites.

Taxonomy. There are six genera in the subfamily Knemidoptinae (family Epidermoptidae). Two genera are important in veterinary medicine. Genus *Knemidocoptes* includes 5 species, with *Knemidocoptes mutans* (parasite of the domestic poultry) and *K. pilae* (in caged birds, mainly budgerigars) being the most important. Genus *Neocnemidocoptes* includes four species, out of which one is parasitic in domestic poultry (*N. laevis*) (Dabert et al. 2011).

Morphology. Mites of genus *Knemidocoptes* (figure 77) are small to medium sized (ca. 400 µm), lack spines, with very short, rudimentary legs and very short rostrum (Russell et al. 2013).

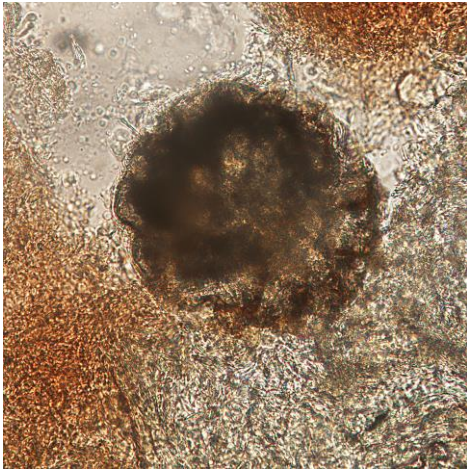


Figure 77. *Knemidocoptes* sp.: general morphology (photo Andrei D. Mihalca)

Biology and life-cycle. Most species in the family Epidermoptidae are parasitic on the skin surface of birds, but some species penetrate deeply into the feather follicles and cause mange-like lesions. The site of parasitism also varies by species. Some species are known as “face mites” are parasitic in the *stratum corneum* of the face and cere (e.g. *K. pilae*), others as “scaly leg mites” parasitic under the scales of on the feet and leg (*K. mutans*) and others as “depluming itch mites”, parasitic the basis of feathers on the body (e.g. *N. laevis*) (Dabert et al. 2011).

Most species are ovoviviparous (the larvae hatch from the eggs while still in the adult female’s reproductive system). The hexapod larvae are deposited by the females and later become octopod protonymphs, deutonymphs and adults.

Epidemiology. Transmission is usually by direct contact or fomites. Knemidocoptic mange is a common

disease of caged birds, especially budgerigars, worldwide.

Disease. The “scaly leg mites” produces typical crusty lesions, which becomes hyperkeratotic (figure 78) and hard, under the form of a proliferative mass (figure 79). Long-term and heavy infestations produce feet, legs and claws deformation, associated with lameness. In severe cases, birds stop moving and feeding and death may occur (Dabert et al. 2011). Scaly leg mites are relatively common also in wild birds (figure 80) (Dabert et al. 2011).

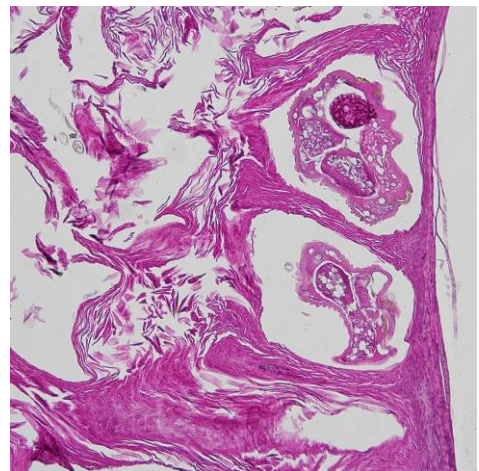


Figure 78. Transversal section of the tarsometatarsus of common chaffinch (*Fringilla coelebs*) infected with *K. jamaicensis* (photo Andrei D. Mihalca)

The infestation with face mites (*K. pilae*) in budgerigars is responsible for mild to severe overgrowth and deformity of the beak (figure 81) which affects significantly normal feeding and grooming. Sometimes, the lesions can extend to the eyelids and legs (Dabert et al. 2011).



Figure 79. Hyperkeratotic lesions on the leg of a domestic rooster (photo Andrei D. Mihalca)



Figure 80. Scaly leg lesions caused by *K. intermedius* in a common raven from Romania (photo Andrei D. Mihalca)

The lesions caused by *N. laevis* produce severe pruritus and feather loss on the back, head and neck of various domestic birds (Galliformes and Anseriformes) (Dabert et al. 2011).

Diagnosis. From the affected areas, a deep skin scarping will reveal the presence of mites with the typical morphology. Take special care when

performing the scrapping in small birds to avoid injury or sudden death from stress.



Figure 81. Hyperkeratotic lesions on the leg of a domestic rooster (photo Andrei D. Mihalca)

Treatment and control. A wide variety of chemical products are available for the control and treatment of Knemidocptid mites in birds. Formulations are designed for dipping, spraying or dusting. The following are available: **pyrethroids** (deltamethrin, flumethrin, cypermethrin) **carbamates** (carbaryl) and **organophosphates** (coumaphos, chlorpyrifos).

In budgerigars, topical or oral formulation with ivermectin is the best therapeutic approach. Two or three treatments at 10 days interval are recommended. Injections in these species should be avoided.

2.4.4. Other astigmatids of veterinary importance

Family Myocoptidae includes species of astigmatid fur mites, parasitic on rodents and marsupials. *Myocoptes musculinus* is a common parasite of house mice, with a worldwide distribution, feeding on epidermal tissue. Under natural conditions, the infestation is usually mild, but in dense colonies of laboratory animals, outbreaks of **myocoptic mange** can occur, with pruritus, oedema, alopecia, mainly on the neck, back and shoulders (Mullen and Oconnor, 2002).

Family Listrophoridae includes mites parasitic in the fur of rodents, lagomorphs and carnivores. The mites strongly attach to the hair shafts of their hosts, feeding with sebaceous secretions. The infestation is usually asymptomatic, but in dense colonies of mice (laboratory animal facilities) or domestic rabbits (farms) clinical signs consisting in alopecia, itching and dermatitis can occur. *Leporacarus gibbus* is a parasite of domestic rabbits causing pruritus and hair loss (Mullen and OConnor, 2002).

Family Atopomelidae comprises various genera parasitic in several groups of mammals (including rodents, marsupials, and primates) with distribution primarily in the southern Hemisphere. One species, *Chirodiscoides caviae* (figure 82) has spread all over the world and is a common parasite of pet and laboratory guinea pigs. Clinical signs can be present in massive infestation, particularly in dense colonies when pruritus and hair loss. Easiest diagnosis is by using the scotch tape method.



Figure 82. *Chirodiscoides caviae*, a common ectoparasite of pet guinea pigs (photo Andrei D. Mihalca)

Family Cytoditidae includes internal parasites of avian hosts, typically infesting the respiratory system and occasionally the peritoneum or various internal organs. *Cytodites nudus* known also as the “chicken air-sac mite” has a worldwide distribution. High infestation levels are associated with mucus hypersecretion with coughing, dyspnoea, pulmonary oedema, pneumonia and even death (Mullen and Oconnor, 2002).

Family Laminosioptidae contains various species of external parasites of birds. The “fowl cyst mite”, *Laminosioptes cysticola* forms yellowish subcutaneous cyst-like nodules of several millimetres in size in various birds (chicken, pheasants, turkeys, geese, pigeons) (Mullen and Oconnor, 2002).

Family Epidermoptidae, known also as “avian skin mites”, includes mites parasitic on the skin or in the feather

follicles of various bird species. *Epidermoptes bilobatus* is a parasite of domestic fowl, known to occasionally cause scaly dermatitis and itching. Other genera of veterinary concern are *Myialges*, *Microlichus* or *Rivoltasia* (Mullen and OConnor, 2002).

3. Insecta

Insects are the most biodiverse class on Earth, comprising more than one million species. Their body is divided into **three main parts: head, thorax and abdomen**. Adults have **three pairs of legs**. In some species, **wings** are present (one or two pairs, depending on the group), while other groups are wingless. Legs and wings are inserted to the thorax. The head has a pair of segmented antennae, the **eyes** (compound or small ocelli) and the **mouth parts**. In parasitic insects, these cephalic structures vary a lot. The eyes may be absent, as well as the antennae and the mouthparts are adapted to various feeding types (chewing, sucking, biting).

The **life cycle** of insects follows two main patterns: **incomplete metamorphosis** (hemimetabolic) and **complete metamorphosis** (holometabolic). In insects with hemimetabolic life cycle, the immature stages resemble the adults (but are smaller) and the pupal stage is missing (i.e. in lice). In insects with holometabolic life cycle, the immature stages differ significantly from the adults and the major change (metamorphosis) takes place during the pupal stage which is a non-feeding stage (Deplazes et al. 2016).

3.1. Lice (Phthiraptera)

Lice (Order Phthiraptera) are a very diverse group of insects, exclusively adapted to parasitism. Several thousands of species are described to

date (Lehane 2005). All lice are dorso-ventrally flattened, wingless insects, relatively small in size (0.4-10 mm in length) with a hemimetabolic (=incomplete metamorphosis) life cycle, comprising adults (males and females), eggs (known as nits) and three nymphal stages (Durden 2002; Deplazes et al. 2016). Lice have generally a high host specificity, and, within a host species, sometimes also a specificity to certain body regions. Lice as a group, have a cosmopolitan distribution. Lice have been traditionally divided into two main groups: the chewing lice (Malophaga) and sucking lice (Anoplura). All developmental stages of lice are parasitic on warm-blooded vertebrates (birds and mammals) (Durden 2002). The two groups differ in the feeding habits (Malophaga feed on skin and skin products while Anoplura generally feed on blood) and can be easily differentiated morphologically (figure 83).

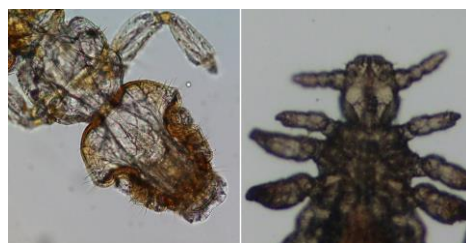


Figure 83. The main difference between chewing lice (left) and sucking lice (right) is the width of the head compared to the thorax (photo Andrei D. Mihalca)

3.1.1. Chewing lice

The chewing lice (Malophaga; Greek: “mallos” = wool; “phagein” = eat) are ectoparasites of birds and mammals (marsupials and placental), with a worldwide distribution.

Taxonomy. The taxonomy of this group is still under debate. In the past, Malophaga was considered a suborder of Phthiraptera and included two main groups of veterinary importance: Amblycera and Ischnocera. Currently, both are widely accepted as suborders of Phthiraptera. They are quite biodiverse group, with more than 2600 species

known. Most of the species are parasitic on wildlife but several are known also from domestic animals (table 4).

Morphology. The body is flattened dorso-ventrally and the head is generally wider than the first segment of the thorax (figures 84-85). The main difference between the two suborders of chewing lice consists in the morphology of the antennae (4 segments in Amblycera, located in a groove lateral to the head; 3-5 segments, free from the head and clearly visible in Ischnocera) and of the maxillary palps (present in Amblycera, absent in Ischnocera) (Durden 2002; Deplazes et al. 2016).

Table 4. Representative species of chewing lice in domestic animals (compiled after Durden 2002; Deplazes et al. 2016)

Host species	Louse species	Family	Suborder
Cattle	<i>Bovicola bovis</i>	Trichodectidae	Ischnocera
Sheep	<i>Bovicola ovis</i>	Trichodectidae	Ischnocera
Goat	<i>Bovicola caprae</i> <i>Bovicola limbatus</i> <i>Bovicola crassipes</i>	Trichodectidae	Ischnocera
Horse	<i>Bovicola equi</i>	Trichodectidae	Ischnocera
Donkey	<i>Bovicola equi asini</i> <i>Bovicola ocellatus</i>	Trichodectidae	Ischnocera
South American camelids	<i>Bovicola breviceps</i>	Trichodectidae	Ischnocera
Dog	<i>Trichodectes canis</i> <i>Heterodoxus spiniger</i>	Trichodectidae Boopidae	Ischnocera Amblycera
Cat	<i>Felicola subrostratus</i>	Trichodectidae	Ischnocera
Guinea pig	<i>Gliricola porcelli</i> <i>Gyropus ovalis</i> <i>Trimenopon hispidum</i>	Gyropidae Trimenoponidae	Amblycera Amblycera
Chicken	<i>Menopon gallinae</i> <i>Menacanthus stramineus</i> <i>Goniocotes gallinae</i> <i>Goniocotes gigas</i> <i>Goniocotes dissimilis</i> <i>Cuclotogaster heterographus</i> <i>Lipeurus caponis</i>	Menoponidae Philopteridae	Amblycera Ischnocera
Turkey	<i>Menacanthus stramineus</i> <i>Chelopistes meleagridis</i> <i>Oxylpeurus polytrapezius</i>	Menoponidae Philopteridae	Amblycera Ischnocera
Dove/pigeons	<i>Hohorstiella lata</i> <i>Columbicola columbae</i> <i>Campanulotes compar</i>	Menoponidae Philopteridae	Amblycera Ischnocera
Goose	<i>Anaticola anseris</i> <i>Anatoecus icterodes</i> <i>Trinoton anserinum</i>	Philopteridae Menoponidae	Ischnocera Amblycera
Duck	<i>Anaticola crassicornis</i> <i>Trinoton querquedulae</i>	Philopteridae Menoponidae	Ischnocera Amblycera

The thorax is usually segmented in 2 or 3 parts. The abdomen (which has 11 segments) is elongated and is protected by sclerotized plates which confer a certain rigidity to the body even when the abdomen is distended. The adult females possess at the caudal part of the abdomen the gonopods, which are used to control and glue the eggs to the hair or the feathers of the host (Durden 2002). Immature stages (nymphs), as in other hemimetabolic insects, resemble adults, but are smaller and lack genital structure.



Figure 84. *Columbicola* sp. from a pigeon (photo Andrei D. Mihalca)

Biology and life cycle. Both orders use mammals and birds as hosts (table 4). Most domestic animal species can act as host for chewing lice, notable exceptions being pigs, rabbits and humans.



Figure 85. *Gliricola porcelli* from a guinea pig (photo Andrei D. Mihalca)

The majority of species are very specific to their host, while others can feed on multiple (but related) host species. Moreover, many species (mainly of avian lice) display site specificity (i.e. some species are found only on the head or others only on the body). (Durden 2002). Typically, chewing lice feed on various skin products (fur, feathers, skin debris, secretions). However, some species (mainly members of Amblycera) can occasionally feed on blood, after biting into the quills of the feathers (Deplazes et al. 2016). The digestion of keratin is achieved by the endosymbiotic bacteria (Deplazes et al. 2016). The reproduction is typically sexual and occurs on the host. However, there are few species which are parthenogenetic. Males usually make up around 1-5% of the total adult population on a host (Durden 2002). The female lice lay around 0.2-10 eggs per day, which they glue to the hair or feathers. The eggs of the lice are known as nits. The first nymphal stage emerges following an

incubation of 4-15 days. Each of the three nymphal stages develops to the next stage in ca. 3-8 days, separated by moulting. The lifespan of adult lice is around 35 days (Durden 2002). Although all lice are permanent parasites, some species of chewing lice can survive off-host for several days (Durden 2002).

Epidemiology. Generally, there are no seasonal differences in the intensity of chewing lice infestations. In large domestic animals, an increase in lice densities have been observed during winters (Durden 2002). The transmission from a host to another is usually by direct contact, including mating or fighting. In mammals, another common way of transmission is from the mother to the offspring during the suckling, while in birds, nest sharing is crucial. As some lice can survive off-host, indirect transfer (via the environment) is also possible. Another interesting way of transmission is via phoresy, when lice attach to larger hematophagous insects (i.e. flies) and move to other hosts (Durden 2002). A particularly interesting louse is *Heterodoxus spiniger* which was originally a parasite of marsupials in Australia and later switched to dingoes. Currently the species is spread worldwide in various carnivores, including domestic dogs (Durden 2002).

Disease. Most of the cases of chewing lice infestation are asymptomatic as the hoist has various defence mechanisms. These include grooming, moulting, hair or feather loss. Hibernation and hormonal changes can also reduce the

lice load. In some wild hosts, lice have their own predators. In animals with concurrent conditions (weak, decubitus etc.), lack of grooming is associated with increased lice densities. Intensity might be increased and also in very young or very old animals (Durden 2002). Generally, the presence of chewing lice induces itching/pruritus, associated with localized alopecia and excoriations (Deplazes et al. 2016).

In heavily infested animals, economic losses are associated with decreased milk production and growth rate but also to losses in the leather industry. Infected sheep rub against hard surfaces and display significant fleece loss (Durden 2002).

In dogs and cats, skin debris is visible in the fur and pruritus is commonly present. In guinea pigs (figure 86) the infestations are common mainly in large groups (i.e. pet shops) and can cause severe stress.

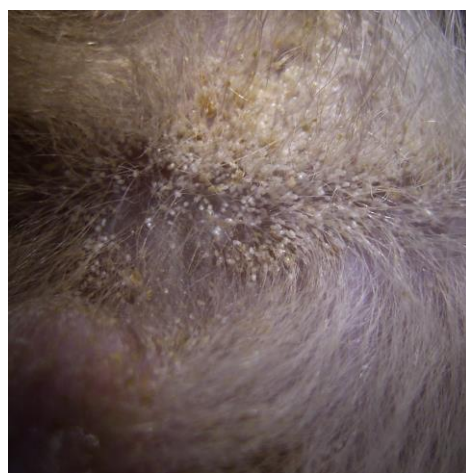


Figure 86. Massive infestation with *Gliricola porcelli* in a guinea pig (photo Andrei D. Mihalca)

In poultry the symptoms are dependent on the type of louse. Most members of Amblycera are able to destroy the quills of the feather, destroying it completely. Members of Ischnocera chew parts of the feathers causing partial feather damage. As in mammals, chewing lice of birds can cause mild to moderate pruritus (Deplazes et al. 2016). Due to intense grooming, lice can indirectly cause digestive problems due to the formation of hair balls, mainly in cats and calves (Durden 2002).

Histological lesions consist in the presence of inflammatory infiltrates, dominated by eosinophils, basophils and mononuclear cells (Deplazes et al. 2016).

Despite limited contact with the host's blood there is evidence which suggest the presence of an immune response to chewing lice. Studies in sheep provided evidence of the presence of specific antibodies, T-cell responses and type I and III hypersensitivity reactions which complicate the skin lesions (Deplazes et al. 2016).

Vectorial role. Chewing lice do not have an important vectorial role. However, some species (i.e. the lice of carnivores) are intermediate host for *Dipylidium caninum* which is transmitted to dogs and cats via ingestion. Some lice of birds are able to transmit avian filariases (Durden 2002; Deplazes et al 2016).

Diagnosis. The presence of lice is normally detectable by visual inspection (figure 87). Although in high infestations the lice (mainly the adults) can be easily detected, in low infestations this might

me challenging. Immature stages are very small and hardly visible with the naked eye. However, the presence of eggs (nits) can be observed by visual inspection, attached to hair or feathers (figure 88), followed by microscopic confirmation.



Figure 87. *Trichodectes canis* on the body of a domestic dog (photo Andrei D. Mihalca)



Figure 88. Nits of *Bovicola equi* on the body of a horse (photo Andrei D. Mihalca)

Certain predilection sites should be preferably examined to increase the sensitivity of diagnosis (head, shoulder, mane, tail, side of the neck etc.). These areas depend on the species of louse, as each has preferences for certain body parts. The scotch tape method is also useful (Deplazes et al. 2016).

Treatment and control. In cattle, effective ways of treatment against chewing lice include **dipping** or **spraying** with organophosphates, pyrethroids or formamidines. All these are effective against nymphs and adults but cannot kill the eggs. As the residual effect is not long enough, the treatment should be repeated 14-20 days later.

Pour-on products are also available with similar insecticides as the products above or in combination (i.e. organophosphates + pyrethroids) or pour-on products with macrocyclic lactones (ivermectin, moxidectin, eprinomectin). Injectable macrocyclic lactones are not effective against chewing lice. **In sheep,** the preventive autumn dipping against psoroptic mange (see chapter 2.4.1) is also effective against lice. **In dogs and cats,** as there are no repellent products against lice, the approach of choice is the treatment of infected animals. Various pharmaceutical forms are available: **spot-on** (fipronil, cyphenothrin, imidacloprid, permethrin, moxidectin, selamectin, metaflumizone), collars (various, see tick control). Note that permethrin is toxic for cats. **In poultry,** the treatment is similar with the one described for the red poultry mites (see chapter 2.2.1).

3.1.2. Sucking lice

The sucking lice (Anoplura; *Greek*: “anoplos” = *unarmed*; “ura” = *tail*) are ectoparasites of placental mammals, with a worldwide distribution. Compared to chewing lice, their main feeding behaviour is hematophagous and, as a result, they induce a different pathology and are important vectors for several medically important pathogens.

Taxonomy. Suborder Anoplura includes various families. The group is less biodiverse than the chewing lice and it currently includes ca. 550 species grouped in 50 genera and 15 families (Durden 2002). Of these, only few are parasitic in domestic animals or humans (table 5).

Morphology. Most of the general morphological features of sucking are similar with those described above for chewing lice. A notable difference which differentiate sucking lice from chewing lice is the head which is slender and narrower than the thorax (figure 89).



Figure 89. *Haematopinus* sp. (photo Andrei D. Mihalca)

Sucking lice lack maxillary palps. The mouthparts are adapted for blood feeding, which is also the main food source. They are visible only during

feeding. All three thoracic segments are fused, and the thorax appears as one single segment (Durden 2002). The antennae are clearly visible and have 3-5 segments (Deplazes et al. 2016).

Table 5. Sucking lice of medical and veterinary importance (compiled after Durden 2002)

Host species	Louse species	Family	Suborder
Cattle	<i>Haematopinus eurysternus</i>	Haematopinidae	Anoplura
	<i>Haematopinus quadripertusus</i>		
	<i>Haematopinus tuberculatus</i>	Linognathidae	Anoplura
	<i>Linognathus vituli</i>		
	<i>Solenopotes capillatus</i>		
Buffalo	<i>Haematopinus tuberculatus</i>	Haematopinidae	Anoplura
Sheep	<i>Linognathus ovillus</i>	Linognathidae	Anoplura
	<i>Linognathus pedalis</i>		
	<i>Linognathus africanus</i>		
Goat	<i>Linognathus africanus</i>	Linognathidae	Anoplura
	<i>Linognathus stenopsis</i>		
Equids	<i>Haematopinus asini</i>	Haematopinidae	Anoplura
Swine	<i>Haematopinus suis</i>	Haematopinidae	Anoplura
Dog	<i>Linognathus setosus</i>	Linognathidae	Anoplura
Rabbit	<i>Haemodipsus ventricosus</i>	Polyplacidae	Anoplura
House mouse	<i>Polyplax serrata</i>	Polyplacidae	Anoplura
	<i>Hoplopleura captiosa</i>	Hoplopleuridae	Anoplura
Rat	<i>Polyplax spinulosa</i>	Polyplacidae	Anoplura
	<i>Hoplopleura pacifica</i>	Hoplopleuridae	Anoplura
Human	<i>Pediculus humanus capitis</i>	Pediculidae	Anoplura
	<i>Pediculus humanus humanus</i>		
	<i>Pthirus pubis</i>	Pthiridae	Anoplura

Biology and life cycle. All main species of domestic mammals have one or several associated sucking louse species. Humans, pigs and rabbits have only sucking lice. Sucking lice do not infest birds. Most species are host specific and some are even site specific. As their name suggests, sucking lice feed primarily on blood. The sucking is enhanced by the presence of strong oesophageal muscles. Digestion of blood is enhanced by the presence of mutualistic microbiota (Deplazes et al. 2016). Blood ingestion is crucial for the production of eggs. The life history of sucking lice is similar in many aspects

with that of chewing lice. Unlike chewing lice, most sucking lice cannot survive more than few hours without a blood meal, hence their off-host survival is limited.

Epidemiology. The sucking lice are distributed worldwide, and the epidemiology of infestation is similar with that described above for chewing lice. Transmission is mainly by direct contact. In humans, the pubic louse or crab louse (*Pthirus pubis*) is transmitted during sexual contact. Seasonal variation has been described for sucking lice of cattle, with higher parasitic loads during winter and spring (Deplazes et al. 2016).

Disease. The presence of sucking lice is more pathogenic to their host than the presence of chewing lice due to the irritation caused by the permanent blood feeding. Salivary components induce severe itching which causes skin lesions due to the intensive pruritus (Deplazes et al. 2016). Although the amount of blood consumed by each louse is negligible (less than 0.1 mg/meal), high intensity infestations can induce anaemia, mainly in young animals. Other clinical signs may include one or more of the following: alopecia, squamous dermatitis, skin thickening and more or less severe pruritus. In farms with heavily infested animals, economical losses due to decreased milk and meat production (Deplazes et al. 2016).

Due to the direct contact of salivary antigens with the host's blood, there is a significant immune response to sucking lice, which protects the host after multiple exposures. This is probably the reason why sucking lice are more common in young animals than in adults. As for chewing lice, occurrences of various types of hypersensitivity are known also in sucking lice infestations (Deplazes et al. 2016).

Vectorial role. Unlike chewing lice, anoplurans, due to their blood sucking feeding can transmit a great variety of pathogens. In domestic animals, sucking lice can transmit the bovine anaplasmosis. However, human body lice (*Pediculus humanus humanus*) are vectors for several important diseases such as: the epidemic typhus (caused by *Rickettsia prowazekii*), the louse-borne

relapsing fever (caused by *Borrelia recurrentis*), or the trench fever (caused by *Bartonella quintana*) (Durdan 2002).

Diagnosis. It is similar with the diagnosis of chewing lice. A careful visual inspection is enough for the detection of adult or immature lice or nits. Often, sucking lice are attached to the skin (figure 90).



Figure 90. *Haematopinus suis* finely attached to the skin of a pig (photo Andrei D. Mihalca)

Treatment and control. In cattle, the treatment follows the same principle as described for chewing lice (see chapter 3.1.1). Additionally, injectable macrocyclic lactones are available. In sheep, the preventive autumn dipping against psoroptic mange (see chapter 2.4.1) is also effective against lice. In pigs, **spraying** or **dipping** with organophosphates, pyrethroids or formamidines are recommended. **Pour-on** products (amitraz, phoxim) are also available. Very commonly used are also **injectable** macrocyclic lactones (ivermectin, doramectin). Treatment

must be repeated after 2-3 weeks. **In dogs and cats**, the treatment is the same as the one described for chewing lice (see chapter 3.1.1).

3.2. Fleas (Siphonaptera)

Fleas are blood-sucking insects which commonly infect wild and domestic animals (mainly dogs and cats) but also humans, with the ability to jump. Except serious dermatological conditions related mainly to allergic reactions, some fleas can be vectors for various pathogens.

Taxonomy. All fleas belong to order Siphonaptera which includes around 2500 species. The most important species found on domestic animals and/or humans are: *Ctenocephalides felis* (cats, dogs, rarely other domestic hosts and humans), *C. canis* (dogs, rarely other domestic hosts and humans) (figure 91), *Pulex irritans* (most domestic animals and humans) (figure 92), *Spilopsyllus cuniculi* (rabbits), *Echidnophaga gallinacea* (chicken, dogs, humans), *Ceratophyllus gallinae* (chicken, rarely cats and human), *Tunga penetrans* (humans, pigs, dogs, cattle) (Deplazes et al. 2016).

Morphology. Fleas are insects in which the adults are adapted to parasitism and are very different morphologically in their larval stage, which live in the environment. Adult fleas have a laterally flattened body, adapted to movement by jumping, with long hind legs. They are usually small, the largest species reaching up to 6 mm. The limits between the three body segments are very fine,

almost not visible. The head is small and the abdomen is large (Deplazes et al. 2016).



Figure 91. *Ctenocephalides canis*: details of the head (photo Andrei D. Mihalca)



Figure 92. *Pulex irritans* (photo Andrei D. Mihalca)

Biology and life-cycle. Fleas are holometabolic insects (complete life cycle). Their developmental stages include eggs, three larval stages, pupa and adults. Only the adults are parasitic and both, the males and the females are

hematophagous. The immature stages live in the environment. When emerging from the pupa, both the males and the females are generally unable to reproduce and they require a blood meal for the activation of this function. Hence, mating takes place after both sexes feed (with some very few exceptions, when mating occurs before the first blood meal). Mating occurs on the host or off-host, depending on the species. (Krasnov, 2008).

In *Ctenocephalides felis*, the females start laying eggs after 24-48 hour following the first blood meal and they lay around 30 eggs per day, daily, for 50-100 days. The eggs fall to ground and are scattered in the habitat of the dog or cat. The larvae (L1) hatch after one week. The larvae (figure 93) will feed on feces of adult fleas but also on flea eggs (cannibalism) and will undergo two moulting (until L3) (Deplazes et al. 2016).



Figure 93. Larval stage of *Ctenocephalides canis*: (photo Andrei D. Mihalca)

The development of larvae can take 7-11 days, under optimal environmental conditions. The completely developed L3 will produce a cocoon in which the pupa will form. The pupal stage will last for 10 to 14 days and will produce the adults. The complete life cycle in indoor conditions can last 3-4 weeks (Deplazes et al. 2016).

Epidemiology. Larvae are sensitive to desiccation but adults can survive in the environment for more than one year. Most fleas of humans and domestic animals have a worldwide distribution. Some (*Tunga*, *Echidnophaga*) are more common in tropical environments. The prevalence in dogs and cats can reach up to 90%. In temperate areas, the highest flea densities are found in the warm season (Deplazes et al. 2016).

Disease. Fleas are responsible for skin reactions including local or even systemic effects. The local effects are mainly erythema and papules, associated with itching of various intensities. In dogs, one of the most common dermatological conditions is the flea bite allergy. Low levels of infestation can results in severe lesions but if allergy if not present, even massive infestations (figure 94) have little clinical impact.

In other species, fleas produce similar lesions and symptoms but allergies are more rare. Chicken with high levels of infestation with *C. gallinae* or *E. gallinacea* (figure 95) may show increased mortalities (Deplazes et al. 2016). Although fleas have certain host preferences, interspecific transmission is not un common (figure 96).



Figure 94. Massive infestation with *Ctenocephalides* sp. in a puppy (photo Andrei D. Mihalca)



Figure 95. Infestation with *Echidnophaga gallinacea* in a chicken (photo David Modrý)

The most well studied and known pathogenic effect is for the fleas of genus *Ctenocephalides* in domestic carnivores. The dominant component is the allergic effect (bothy immediate and delayed), caused by various components of the flea saliva. As a consequence, histamine is released and this causes erythema and oedema which develop very fast around the bites. Not all dogs develop flea bite

allergy. In those with severe reactions, higher levels of anti-flea antigen antibodies are found (IgG, IgE) and few bites are enough to trigger the allergy (Deplazes et al. 2016).



Figure 96. Infestation with *Echidnophaga gallinacea* in a dog (photo Andrei D. Mihalca)



Figure 97. *Pulex irritans* biting human skin (photo Andrei D. Mihalca)

Human infested with fleas (figure 97) display similar clinical signs, with pruritus as the dominant symptom.

Vectorial role. Fleas are very important vectors for both animal and human pathogens. The following pathogens are transmitted by fleas: *Yersinia pestis* (the agent of plague, transmitted by the rat flea *Xenopsylla cheopis*), *Rickettsia typhi* (the agent of endemic typhus, transmitted by *Xenopsylla cheopis* but also by *Ctenocephalides felis*), *Rickettsia felis* (the agent of flea borne spotted fever, transmitted by *Xenopsylla cheopis* and *Archeopsylla erinacei*), and *Bartonella henselae* (the agent of cat scratch disease, transmitted by *Ctenocephalides felis*). Fleas transmit to dogs the microfilariae of *Acanthocheilonomes reconditum*.

Additionally, fleas are intermediate host (which has a different meaning than a vector) for cestodes like *Dipylidium caninum* or various species of *Hymenolepis*.

Diagnosis. Fleas can be detected directly by visual inspection on the fur of animals. As they are lucifugous, careful attention should be paid to the hidden areas (ventral part, areas with dense hair). A fine comb or brush can be used also for this purpose. Failing to find adult fleas on animals but with detection of flea feces has also diagnostic value. Flea feces are dark brown particles at the basis of the hair, close to the fur. If they are mixed with water on a white paper, they will dissolve in a dark red material, indicating the presence of digested blood. The diagnosis of flea bite allergy should be differentiated from other allergic condition with similar clinical pictures. Intradermal test with

flea antigens are available but yield inconstant results.

Treatment and control. It is essential to understand that only 5% of the flea population lives actually on the dog or cat, while the remaining 95% is found in the environment (as eggs, larvae or pupae). Hence, a strategic approach should consider eliminating both components of the flea population: on-host and off-host.

The **on-host treatment** should be applied to all dogs and cats in the household, not only to those found to be infested. The number of products available for the treatment of dogs and cats against fleas is high, and their efficacy is different, due to various factors, including chemical resistance. There are various categories. **Spot-on** products are found as single chemicals (fipronil, imidacloprid, pyriprole, selamectin, spinetoram) or most often a combination of two or three chemical (fipronil + methoprene, fipronil + methoprene + cyphenothrin, fipronil + methoprene + etofenprox, fipronil + methoprene + amitraz, imidacloprid + permethrin, imidacloprid + permethrin + pyriproxyfen, imidacloprid + moxidectin). Usually spot-on products offer a one-month protection against fleas. **Collars** impregnated with insecticides are also commonly used. Most of the commercial brands include a single active compound. Examples are: carbaryl, propoxur, imidacloprid, diazinon, deltamethrin, flumethrin, permethrin etc. Collars usually offer a longer protection than spot-on products, but resistance is more common. **Oral**

products (tablets, pills, chewable) have a systemic effect, after the active compound is absorbed from the intestine to the blood. There are various compounds available, some of them including a single active ingredient (lufenuron, nitenpyram, spinosad, fluralaner, afoxolaner, sarolaner, lotilaner) other combinations of various active ingredients, including anthelmintics (lufenuron, + milbemycin oxime, lufenuron + milbemycin oxime + praziquantel, afoxolaner + milbemycin oxime).

There are various other products applied externally on dogs and cats against fleas (**shampoos, soaps, sprays, powders**) but the protection offered is very short, often 2-4 days. They are usually used to kill on fast the fleas mainly in animals with massive infestations, followed by administration of another product which offers a longer protection (spot-on, collar, oral products).

The **control of fleas in the environment** (off-host) is essential for a successful control strategy. It is also true that modern products used for on-host flea-control are strong enough to make the off-host control less essential, but this is still important if the infective pressure is high. The environmental control targets mainly the larval stages which are present in the habitat where the dogs or cats spend most of their time: carpets, rugs, floor of the enclosure etc. The following insecticides can be used for the off-host control of fleas: **benzoylureas** (diflubenzuron, triflumuron), **carbamates** (carbaryl, propoxur),

juvenile hormone analogues (methoprene, pyriproxyfen), **neonicotinoids** (imidacloprid), **organophosphates** (chlorfenvinphos, chlorpyrifos, coumaphos, diazinon, dichlorvos), **phenylpyrazoles** (fipronil), **pyrethroids** (cyfluthrin, cypermethrin, deltamethrin, permethrin),

3.3. Biting Diptera

Order Diptera are characterized by the presence of only two functional wings in adults and by the absence of legs in the larval stages. They are considered to be the most important group of insects from medical point of view, as the representatives of Diptera are vectors for the most devastating human diseases, such as malaria.

The medical importance of dipterans resides either in their blood sucking capacity, usually doubled by a more or less important vectorial role or in other cases, in the ability of larvae to develop in various tissues of a vertebrate hosts.

3.3.1. Mosquitoes (Culicidae)

Mosquitoes are the most well-known and the most important disease vectors for humans. In animals they are also important vectors of disease. They have a worldwide distribution and some medically important species became invasive and pose a significant risk to human or animal health.

Taxonomy. Due to the large diversity of the group and to the huge interest of researchers, there are various debates about the subdivisions of this group. Estimates suggest the existence of more

than 3500 mosquito species, distributed in many genera. Many species are important vectors, but as usually the associations are not too specific, it is not relevant to list here all the species of medical or veterinary importance. Mosquitoes (family Culicidae) are divided into two subfamilies: Anophelinae and Culicinae. The most important genera are *Anopheles* (Anophelinae), *Aedes* and *Culex* (Culicinae). However, some of these genera were divided into several subgenera, some of them being currently elevated to genus level. The highest species richness is in tropical areas. In Europe, there are around 100 species present, some of them invasive. Among them, the most important are the Asian tiger mosquito (*Aedes albopictus*) and the Asian bush mosquito (*Aedes japonicus*) (Deplazes et al. 2016).

Morphology. Mosquitoes are small insects (4-10 mm), have a slender and long body, long legs, and long and narrow wings (figure 98). The wings and body are covered with scales. The mouthparts (proboscis) of females are long and adapted to bloodsucking. The main morphological difference between males and females which makes their differentiation relatively easy is the aspect of the antennae. In males, these are plumose (long hairs), while in females they are pilose (short hairs) (Russell et al. 2013; Deplazes et al. 2016).

Biology and life-cycle. Mating occurs immediately after adults emerge from the pupae.



Figure 98. A mosquito (*Aedes caspius*) feeding on a human (photo Andrei D. Mihalca)

Mating takes place usually at sunset, when swarms are formed typically at the tops of trees or bushes, where males and virgin females group together. When a male-female couple is formed after the male recognizes a female from short distance, the pair leaves the swarm and insemination takes place. Females usually require a blood meal for the ovarian development and for oviposition. Females lay between 100 and 150 eggs, in batches (in *Culex*) or singly (in *Anopheles* and *Aedes*). The eggs are laid on the water surface, on land or objects very close to the shore or on moist surfaces, depending on the species. Eggs are laid at night, and due to special floating structures, they do not sink. After 1-3 days, larvae hatch. The larvae usually develop in the water but they breathe atmospheric air. After passing through 4 instars, they become pupae. In 8-21 days, new adults are formed (Russell et al. 2013; Deplazes et al. 2016).

Most mosquitoes are active during the dusk or dawn and nocturnal. Species living in bushes or forests are also biting during the daylight. Many species lack host specificity, feeding on a wide range of hosts, while other prefer certain groups: ornithophilic (feeding on birds), mammalophilic (feeding on mammals) or anthropophilic (feeding on humans) (Deplazes et al. 2016).

Epidemiology. The species distribution is highly dependent on the preferred habitat for mating and larval development, which is variable according to the species. Mosquitoes of genus *Anopheles* prefer stagnant and permanent waters, rich in aquatic vegetation and close to human settlements. Mosquitoes in genus *Aedes* prefer flooded forests (*Ae. vexans*), swampy forests (*Ae. communis*), small water containers, including artificial ones like car tires (*Ae. albopictus*, *Ae. japonicus*) or tree holes (*Ae. geniculatus*). Species in genus *Culex* are common around human settlements where small containers are available (Deplazes et al. 2016). Mosquitoes are highly seasonal, their activity, feeding, breeding and abundance depending on the temperature, rains, winds etc.

Disease. Despite their main medical importance resides in the vectorial capacity, mosquitoes are also an important source of nuisance to humans and animals. Their bite is usually itchy due to salivary components. Massive mosquito attacks are able to cause significant disturbance and even influence performance (Deplazes et al. 2016).

Vectorial role. Mosquitoes are vectors for an exceptionally high number of pathogens of human and veterinary importance, most of them also with zoonotic potential. Several arboviruses like *Flaviviridae* (yellow fever virus, Zika virus, dengue viruses, Japanese encephalitis virus, St. Louis encephalitis virus, Murray Valley encephalitis virus, West Nile virus, Kunjin virus, Usutu virus), *Togaviridae* (Sindbis virus, Ross River virus, Barmah Forest virus, Chikungunya virus, Mayaro virus, Eastern equine encephalitis virus, Western equine encephalitis virus, Venezuelan equine encephalitis virus), *Bunyaviridae* (La Crosse virus, Oropouche virus, Rift Valley fever virus), *Rhabdoviridae* (bovine ephemeral fever virus) are vectored by mosquitoes. Mosquito-borne bacteria such as *Eperythrozoon* are distributed worldwide and impact animal health. Probably the most important and well-known mosquito-borne pathogens are hemosporidia of genus *Plasmodium*, the agent of human and animal malaria. Mosquitoes are also important vectors for helminths like *Wuchereria bancrofti*, *Brugia malayi* or *Brugia timori* (all agents of human lymphatic filariases) and animal filariases (*Dirofilaria immitis* or the canine heartworm, *D. repens*, *Setaria* spp. etc.) (Russell et al. 2013).

Diagnosis. Mosquitoes can be recognized by their typical behaviour, morphology and sound, but species identification should be performed by trained medical entomologists.

Treatment and control. The use of insect repellents is essential for the

prevention of mosquito-borne diseases. Due to the huge clinical importance and severity of canine heartworm (*D. immitis*) most of the repellent products used against mosquito bites in veterinary medicine were developed for dogs. Collars impregnated with deltamethrin or spot-on products are widely used. In horses, spray or gel formulations with ivermectin or permethrin applied against flies are also effective on short term (hours) against mosquitoes (Deplazes et al. 2016).

However, the most effective control against mosquitoes are the strategic public health measures targeted on the reduction of populations in the environment. Control of larvae is achieved applications of larvicidal products or by the reduction or elimination of breeding sites. Adult mosquitoes are controlled in the environment by mass applications of pyrethroids or organophosphates using misting or spraying (Deplazes et al. 2016).

3.3.2. Sandflies (Psychodidae)

Sandflies are small hematophagous insects, with a worldwide distribution with their medical and veterinary importance residing mostly in the vector role for various species of *Leishmania*.

Taxonomy. Sandflies represent a subfamily (Phlebotominae) in the family Psychodidae. There are around 800 species of sandflies in six genera. The most important genera are *Phlebotomus* and *Sergentomyia* in the Old World and *Lutzomyia* in the New World (Russell et al. 2013). Among the most important

species of genus *Phlebotomus* are those which pose a high vectorial capacity for various pathogens, particularly leishmaniasis: *P. papatasi*, *P. perniciosus*, *P. neglectus*, *P. mascittii* etc. (Russell et al. 2013).

Morphology. Sandflies are small, brownish coloured dipterans (ca 5 mm in length), with a narrow body, hairy surface, long legs and large black eyes (figure 99). The wings are also narrow, lanceolate and hairy. When at rest, they are kept straight up above the thorax. The head holds two long antennae (Wall and Shearer, 1997). The mouthparts are somehow long, but the mandibles are functional only in females (Russell et al. 2013).



Figure 99. *Phlebotomus papatasi* (photo David Modrý)

Biology and life-cycle. Females of all species are hematophagous, feeding on a wide range of vertebrates. Species in genus *Phlebotomus* are feeding on mammals, those in genus *Sergentomyia* prefer reptiles and amphibians while

Lutzomyia feeds on both reptiles and mammals. They usually feed during the night, dusk, or dawn. After the blood is ingested, in the midgut it is surrounded by a peritrophic membrane which also influences the development of *Leishmania*. They are poor fliers and are not generally found more than 100-200 m away from the host habitat (burrows, caves, stables). They do not fly if the weather is windy. Males feed exclusively on vegetal juices. Most species are exophilic, but some adapted to endophilic lifestyle, being found commonly inside the houses or animal enclosures like shelters or stables (Russell et al. 2013).

Females lay 50-100 eggs per batch, usually in crevices or cracks on the ground, leaf litter or trees. One side of the eggs is flat and the other convex. Most species cannot lay eggs before they take a blood meal. When the eggs are laid they are white and become dark (brown or black) after several hours. After hatching, larvae pass through four instars before becoming pupa. Unlike in mosquitoes, biting midges and black flies, the immature stages of sandflies are more terrestrial than aquatic. However, they develop in moist environment and are sensitive to desiccation. The larvae feed on organic debris. Pupa is attached to the substratum by the larval sheath. The entire life cycle takes usually between 6 and 10 weeks, depending on the species and environmental conditions (Wall and Shearer, 1997; Russell et al. 2013).

Epidemiology. They have a worldwide distribution. However, the diversity and

abundance is higher in regions with warm climate. In Europe, they are common in the Mediterranean regions and less common or absent at more northern latitudes. As the full life cycle is relatively long, the number of generations per year is limited. As for the warmer temperate regions of the Palearctic there are two generations per year. The abundance is also variable according to environmental conditions, mainly rainfall and temperature (Russell et al. 2013; Deplazes et al. 2016).

Disease. Unlike other biting dipterans, sandflies are usually not abundant enough to become a nuisance for humans and animals and their main medical and veterinary role consists in their importance as vectors. However, despite their small size, the bite is painful.

Vectorial role. The most important diseases vectored by sandflies are leishmaniasis of both animals (mainly dogs) and humans, produced by various species of genus *Leishmania* worldwide. A group of sandfly-borne pathogens which is receiving an increased attention are the fleboviruses. There are many species of fleboviruses, most of them causing flu-like illness in humans. The Toscana virus (also a flebovirus) is responsible for meningoencephalitis in humans. Several rhabdoviruses (i.e. vesicular stomatitis viruses) have been also associated with sandfly transmission (Russell et al. 2013).

Diagnosis. Finding sandflies biting animals is exceptionally rare. For the local surveillance, special traps are used. Species identification follows

morphological criteria, or, more recently molecular or spectrophotometric methods.

Treatment and control. Main measures consist in the prevention of bites, mainly in dogs. There are various formulations available for dogs. Deltamethrin-impregnated collars (4% concentration) have a repellent effect against sandflies lasting from one to six weeks. A combination of permethrin with imidacloprid (as spot-on formulation) protects the dogs as quickly as several hours after administration and the effect lasts for 3-4 weeks (ESCCAP guidelines). Prevention of sandfly bites can be reduced also by avoiding the outdoor access of dogs during the dusk, night and dawn, use of fine mesh nets. Elimination of sites used by sandflies as breeding sites (organic matter deposits, garbage) is also an effective measure to reduce the population densities. Similarly, the use of environmental insecticides for mosquito control is also effective against sandflies (ESCCAP guidelines). In areas endemic for canine leishmaniasis, commercial vaccines are available, but their efficacy in the control of the disease remains to be more extensively studied.

3.3.3. Black flies (Simuliidae)

Black flies are a diverse group of hematophagous insects, with worldwide distribution, feeding on a great variety of hosts including humans.

Taxonomy. There are more than 2100 species of black flies assigned to 26 genera. Of these, only few genera are considered to be medically and

veterinary relevant, among which, the most important and biodiverse is genus *Simulium*. Genus *Simulium* includes about 1720 species, distributed in both hemispheres and all biogeographical regions (Russell et al. 2013). The most important species are *Simulium columbaschense* (in Southern and Central Europe), *S. equinum*, *S. erythrocephalum* and *S. ornatum* (in Western Europe), *S. kurenze* (in Russia), *S. venustum*, *S. vittatum*, *S. pecuarum* and *S. meridionale* (in USA) and *S. arcticum* (in Canada) (Wall and Shearer, 1997).

Morphology. Black flies are small (1-5 mm) insects, with a stout body, humped thorax and broad wings. However, they are not as small as biting midges and they have shorter antennae. As they are diurnal, they have well-developed eyes. The palps are long and consist of five segments. The wings are well-developed and can sustain a flight of more than 100 km in still air (Russell et al. 2013, Wall and Shearer, 1997). The name of “black flies” is related to the often black colour of the adults. However, in some species this might be misleading, as their colour might vary from black to grey or even dark yellow (Wall and Shearer, 1997).

Biology and life-cycle. Development is always in flowing waters. The females lay between 150 and 600 eggs (more commonly 200-300 eggs), usually in sticky masses on partially submerged natural substrates (stones, floating branches etc.) or directly into the water from where they sink to the bottom. Sometimes, several females lay their eggs in collective masses in close vicinity. In other species, females are

able to immerse under water and deposit the eggs on submerged objects. Larvae hatch from the eggs after 6-12 days. The newly emerged larvae produce a silk thread which is used for drifting downstream until a suitable settling place like a stone, rock or a stem. Here, they produce more silk and use their posterior hooks to attach. Such settling sites are usually fast flowing currents, as larvae need highly oxygenated water for development. If needed, larvae can use the same strategy to move further downstream. Larvae pass through 6 to 9 instars in the course of few weeks up to one year, depending on the species and local conditions. Some species overwinter as larvae. The final stage turns into a pupa which is normally surrounded by a cocoon, attached to submerged rocks, close to the water surface. The pupa does not feed. Adults emerge from the pupa and, using an air bubble, float to the surface and fly (Wall and Shearer, 1997; Russell et al. 2013).

Both adult males and females typically feed on plant nectar. However, females need a blood meal for being able to produce eggs. A complete blood meal requires 4-5 minutes. Unlike other blood feeding insects like sandflies, mosquitoes or biting midges, simuliids are generally diurnal (Wall and Shearer, 1997; Russell et al. 2013).

Epidemiology. Although they have a worldwide distribution, black flies are economically important mainly in areas with high animal densities in North America and Eastern Europe. In Europe, black flies are active from March to November, but large densities are more

common during spring. In the active season, black flies are biting from early morning to evening. The distribution of simuliids is highly dependent on the existence of a suitable habitat for larvae (large river beds, in Europe mainly the Danube) (Deplazes et al. 2016).

Disease. Black flies are a significant pest of humans and animals, mainly livestock, with a high medical and economic importance. The most affected animal species are horses, cattle and poultry. Their bite is significantly painful and even low insect density and few bites cause important stress to animals with consequent decreased production. Studies in Australia showed that black flies can reduce the milk production with ca 15%. The main pathogenetic mechanism is related to the toxins injected with the saliva which are responsible for vascular damage. The main lesions associated with the toxic effect are haemorrhagic lesions in the skin, petechial bleeding on the internal organs, oedema of the skin, subcutaneous tissues and internal organs, including severe pulmonary oedema associated with dyspnoea, tachypnoea. Incoordination and recumbency are not uncommon in severe cases and are associated with petechial haemorrhages in the brain. As local densities can reach impressive values (highest world density reported was around 1 million black flies per 1 square metre), mass attacks are common and are able to cause sudden death in cattle. Around 10,000 bites per cattle are enough to cause death in few hours. Cattle which pass several grazing

seasons and are exposed to prolonged simulids bites are less sensitive to such symptoms, suggesting the development a protective immunity. The bite of simulids is also highly allergenic, causing important cutaneous or general reaction. Black fly bites have been associated in horses with the summer eczema. Other species than cattle and wild ruminants are rarely affected by simulidotoxicosis (Wall and Shearer, 1997; Russell et al. 2013; Deplazes et al. 2016).

Vectorial role. Black flies are vectors for several pathogens, the most important being *Onchocerca volvulus*, the agent of river blindness in humans from Africa and Central and South America. Simulids act as vectors also for other *Onchocerca* species parasitic in cattle (*O. gutturosa*, *O. gibsoni*, *O. lienalis*, *O. ochengi*, *O. armillata*) and horses (*O. cervicalis*, *O. reticulata*). Simulids are also known to transmit the protozoa of genus *Leucocytozoon* in birds but also viruses of cattle and horses (eastern equine encephalitis, vesicular stomatitis) (Wall and Shearer, 1997; Russell et al. 2013).

Diagnosis. In cattle, the clinical picture (haemorrhagic spots on the skin during the grazing season) is highly suggestive. For confirmation, black flies should be collected and identified from the animals or from their vicinity. Differential diagnosis against grass tetany is indicated (Deplazes et al. 2016).

Treatment and control. The most effective mean of control targets the larvae and their habitat. Adults populations can be temporarily reduced

by fogging and misting. Pour-on formulations are also efficient on short term to reduce the bites. The most commonly used are the formulations based on pyrethroids and organophosphates. Ear tags are not efficient. In areas with high densities of simulids, night grazing is recommended. Grazing in rainy or chilly days also reduces the bite probability (Russell et al. 2013; Deplazes et al. 2016). Cattle with symptoms of simulidotoxicosis should be promptly removed from the pasture and treated symptomatically with anti-inflammatory drugs and calcium infusion to reduce the impact of toxins and to resolve the vascular dysfunctions (Deplazes et al. 2016).

3.3.4. Biting midges (Ceratopogonidae)

Biting midges are an extremely divers group (more than 6000 species in ca. 125 genera) of parasitic hematophagous dipterans, able to cause significant discomfort to humans and animals worldwide. They are also important vectors for animal pathogens, including the bluetongue virus.

Taxonomy. The most important and large genus is *Culicoides*, which includes more than 1300 extant species, only few of them having a real veterinary importance. Certain species are responsible for summer dermatitis in livestock and horses, the most important being *C. pulicaris* in Europe, *C. robertsi* in Australia and *C. insignis*, *C. steliifer* and *C. venustus* in USA. Other species of veterinary importance include *C. obsoletus*, *C. impunctatus*, and *C. sibirica*

in Europe and Asia and *C. furens*, and *C. denningi* in North America. Two species are particularly important as vectors for bluetongue: *C. imicola* in Africa and Europe and *C. variipennis* in North America (Wall and Shearer, 1997). Additionally, there are several species responsible for human bites and discomfort mainly in tropical and subtropical areas of the world (Russell et al. 2013).

Morphology. Biting midges are small flies (1-4 mm in length) with short legs and relatively long antennae (figure 100). The adults are grey or brownish-black. The head is small and the thorax is humped. They have characteristic wings which are membranous, hairy and spotted (figure 101). At rest, the wings are folded over the abdomen one over the other (scissor-like). The differentiation from other midges (i.e. non-biting midges) is based on the presence in biting midges of a forked media vein (Wall and Shearer, 1997; Russell et al. 2013).



Figure 100. *Culicoides* sp.: general morphology of the body (photo Andrei D. Mihalca)



Figure 101. *Culicoides pulicaris*: typical pattern of the wing (photo Andrei D. Mihalca)

Biology and life-cycle. Only the females are hematophagous and their bite is usually painful. Some species feed mainly during twilight or the night, others are diurnal. Their host finding behaviour is based on CO₂, odour and heat produced by the hosts. Some species are host specific, feeding only on certain vertebrate species, while others can feed on multiple hosts. Biting midges feed on birds and mammals. Females lay between 25 and 450 eggs (depending on the species) in humid ground, marshes or decaying vegetation. In most species, the eggs hatch in a few days. There are a few species in which the eggs are seasonally dormant (over the summer or over the winter). The larvae are vermiform, with 11 body segments and no appendages. They are generally aquatic and live in water-filled holes, swamps, marshland, lake and stream edges, tree holes, dung, etc. The habitat preferences are related to the species. There are four larval stages, separated by moults (ecdysis). Usually the larval development lasts up to seven months; hence, in temperate species, there is only one generation per year. The last moult produces the pupa, a short-living and non-feeding stage. The pupae produce the winged adults. Adults are usually found around the breeding sites,

as they are poor fliers and do not move on long distances. Nevertheless, they can be dispersed to long distances by winds. The total duration of the life cycle is highly variable and ranges from 2-3 weeks in dung-breeding species up to two years in arctic species. Overwintering in the temperate regions usually occurs in the larval stage (Wall and Shearer, 1997; Russell et al. 2013; Deplazes et al. 2016).

Epidemiology. Members of the genus occur worldwide, from tropical to arctic regions. However, individual species have a more limited distribution range. In Europe, biting midges are active from April to December, with a peak in July-September (Deplazes et al. 2016).

Disease. Despite their small size, the bite of *Culicoides* is painful, and simultaneous or sustained bites by large numbers of midges can produce severe irritations, intense pruritus, skin blistering and significant stress to livestock or humans (figure 102).



Figure 102. Erythematous dermatitis following *Culicoides* bites in a human patient (photo Andrei D. Mihalca)

Intense pruritus related to immediate-type hypersensitivity reactions has been described in horses (known as “sweet itch”, “Queensland itch” or “summer dermatitis”). Native ponies in the UK and Icelandic horses imported to Europe seem to be more susceptible. The irritations with hair loss are typically located on the back, withers and base of the tail and are aggravated by self-inflicted traumatic lesions due to intensive scratching. Chronic persistence of the exposure to bites leads to hyperpigmentation and skin thickening (Wall and Shearer, 1997; Deplazes et al. 2016). Studies have shown that the allergic reactions in horses appear for the first time after 3-5 grazing seasons. The allergic reaction is triggered by the saliva of biting midges (Deplazes et al. 2016).

Vectorial role. Although *Culicoides* spp. do not pose a major threat as vectors for human diseases, there are several pathogens of veterinary importance transmitted by biting midges. They act as mechanical vectors for filarioid nematodes of cattle or horses (*Onchocerca* spp.), or humans (*Mansonella*) and to several protozoans in avian (*Haemoproteus*, *Leucocytozoon*) or mammalian (*Hepatozoon*) hosts. However, the most important pathogens vectored by biting midges are viruses. Among these, prominent examples include the bluetongue virus, African horse sickness virus, eastern equine encephalitis virus, and bovine ephemeral fever virus. Other *Culicoides*-borne viruses include the Akabane virus, Aino virus, Oropoche virus or the

epizootic haemorrhagic fever virus (Wall and Shearer, 1997; Russell et al. 2013).

Diagnosis. Presence of small biting insects with the specific morphology during the warm season and evident signs of distress or skin lesions are indicative for the *Culicoides*. Morphological identification is difficult, hence modern and sensitive methods such as PCR or MALDI-TOF are used (Deplazes et al. 2016). The skin reactions should be differentiated from other conditions (photosensitivity, mange) or other types of allergy. Allergen testing is commercially available for certain *Culicoides* species (Deplazes et al. 2016).

Treatment and control. Most advancements in the control of biting midges are related to the development of new holiday areas, as biting midges are famous for causing distress in tourists. These include mainly environmental interventions to reduce egg and larval development (Russell et al. 2013). Prevention of bites is important mainly in horses which are sensitive to allergic reaction. Bites can be reduced by using an “eczema blanket” which should cover a large body surface for increased efficacy. Additionally, weekly pyrethroids (pour-on) or other repellent products (ear tags) should be applied to keep the biting midges away. When allergic reactions develop, antihistaminic drugs and corticosteroids are indicated. Vaccination against bluetongue is recommended in endemic areas (Deplazes et al. 2016).

3.3.5. Horse flies (Tabanidae)

Tabanids are large biting dipterans, known also as horse flies, although they feed on many animal species, mainly livestock. They bite also humans. Their medical and veterinary importance resides mainly in the painful bite and their role of mechanical vectors.

Taxonomy. The family Tabanidae include around 4400 species divided in more than 144 genera. However, only few genera are of veterinary importance: *Tabanus*, *Haematopota*, *Hybomitra* and *Chrysops*.

Morphology. Tabanids are large (6 to 30 mm) insects, with a robust body, a wide head and very large, well-developed eyes (figure 103). The body is usually dark and striped, and the eyes are often coloured or patterned. The veins on the wings are very evident (Russell et al. 2013).

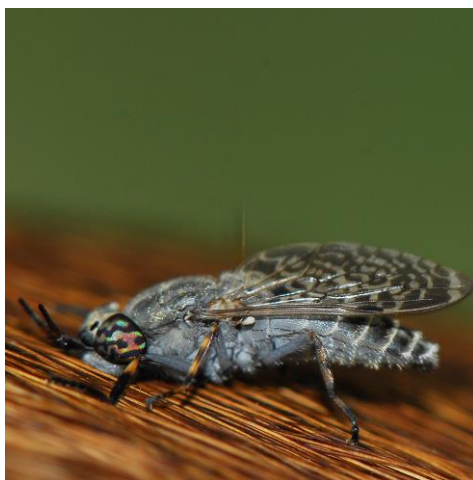


Figure 103. A tabanid feeding on horse (photo Andrei D. Mihalca)

Biology and life-cycle. Females are oviparous. They lay 100-800 eggs in a single mass. Depending on the species, eggs are deposited in humid soil or on plants. Larvae hatch after 2-21 days, depending on the environmental factors and on the species. The tabanids larvae are predatory and feed on a wide variety of larvae of other dipterans and sometimes display a cannibalistic behaviour. There are several larval stages, from 6 to 13, followed by the pupa. In some species, the larval stage can last for 2-3 years. Adults are generally short-lived (2-3 weeks). Mating is in flight. (Baldacchino et al. 2014).

Most species are diurnal. In general, with few exceptions, female tabanids require a blood meal for oviposition. The host-seeking behaviour is visual and olfactory (Russell et al. 2013).

Epidemiology. The most important genera have a different distribution: *Tabanus* (worldwide), *Haematopota* (Europe, Asia, Africa), *Chrysops* (mainly Europe, America, Asia). Tabanids are most active around ecotones (i.e. forest-pasture interface). Their activity is highly seasonal, with maximal values at 25°C (Russell et al. 2013; Baldacchino et al. 2014).

Disease. Tabanids have a painful bite and a persistent biting behaviour, which make them nuisance pests for people and animals, mainly livestock. Areas with abundant tabanids populations are negatively affected due to the impact on tourism, outdoor activities (trekking, fishing, camping, swimming) and farming (Baldacchino et al. 2014).

Tabanids are considered an important pest mainly for horses and cattle (figure 104).



Figure 104. Tabanids are a nuisance to livestock, producing stress and reduced feeding like in this cows evidently disturbed by large numbers attacking her (photo Andrei D. Mihalca)

Except the painful bite, as tabanids are large insects, the blood loss associated with feeding is important, ranging from 20 to 600 μ l per bite, depending on the species. The blood continues after the bite by oozing and can be aggravated by opportunistic blood-feeding flies. Bite sites can be used by myiasis causing flies for oviposition. Often the bites result in local skin reactions such as nodules. High densities are also responsible for decreased milk production and weight loss mainly in cattle, due to impaired feeding (Baldacchino et al. 2014).

Vectorial role. Together with stable flies (*Stomoxys*), tabanids are the most important mechanical vectors of animal diseases. They have been associated

with the mechanical transmission of viruses (equine infectious anaemia virus, bovine leukosis virus, bovine viral diarrhoea virus, hog cholera virus, vesicular stomatitis virus, rinderpest virus), bacteria (*Anaplasma marginale*, *Francisella tularensis*, *Bacillus anthracis*, *Clostridium chauvoei*, *Pasteurella multocida*, *Brucella* spp., *Listeria monocytogenes*, *Erysipelothrix rhusiopathiae*, *Ehrlichia risticii*), protozoa (*Besnoitia besnoiti*, *Trypanosoma evansi*, *T. vivax*, *T. theileri*, *T. equiperdum*, *T. congolense*, *T. brucei*, *Haemoproteus metchnikovi*). Additionally, tabanids are biological vectors for several species of filaria nematodes: *Loa loa*, *Elaeophora schneideri*, *Dirofilaria repens*, *D. roemeri* (Baldacchino et al. 2014).

Diagnosis. Tabanids are easily recognizable on the body of large livestock during the summer based on their size and morphology. However, species identification requires a medical entomologist.

Treatment and control. Tabanids are hard to control. In order to reduce the impact of the attacks during summer, insecticides are used. Pour-on pyrethroids (permethrin 1%, cypermethrin, deltamethrin) have been used with limited efficacy in cattle. Ear tags with permethrin 10% are also moderately effective. In both cases, the effect is limited to 2-3 weeks after the application. Fenvalerate sprays applied on cattle reduce the feeding for few days and they have to be applied continuously throughout the grazing season, which is not practical. Except

insecticides, the use of various repellents has been shown to have certain efficacy. The most effective repellent against tabanids is DEET 75%, but its effect last only for few hours. Moreover, in horses DEET is responsible for adverse reactions such as salivation and dermatitis. Oxamate 20% was an effective repellent against tabanids for 12 hours. Essential plant derived oils have been recently tested with promising results (Baldacchino et al. 2014).

Other methods used for tabanids control include the use of attractant-baited traps around the animals, biological control (using predator wasps), grazing management (at least 200 m away from the forest margin, providing shelters on the pastures), smoke repellent etc. (Baldacchino et al. 2014).

3.3.6. Louse flies and keds (Hippoboscidae)

Unlike most other blood-sucking flies, keds and louse flies are rather permanent ectoparasites, as they tend to remain on their hosts for most of their lives.

Taxonomy. Hippoboscidae is a relatively small group, comprising around 200 species. Three genera are of veterinary importance. Genus *Melophagus* (*M. ovinus* or the sheep ked), genus *Hippobosca* (*H. longipennis* in carnivores (figure 105); *H. equina* in horses and *H. camelina* in dromedaries) and genus *Lipoptena* (*L. cervi* (figure 106) and *L. capreoli* in deer). Many other genera (and the vast majority of Hippoboscidae) are parasites of birds

(i.e. *Ornithomya*) (Russell et al. 2013; Deplazes et al. 2016).



Figure 105. Massive attack of *Hippobosca longipennis* on a domestic dog (photo Andrei D. Mihalca)



Figure 106. *Lipoptena cervi* on a deer (photo Andrei D. Mihalca)

Morphology. The body is dorsoventrally flattened (hence the name of louse flies), with robust legs. They are relatively large (1.5-12 mm). The presence of wings is dependent on the species. In

winged species (i.e. *Hippobosca*, *Lipoptena* spp.), they are long and broad. In certain winged species (i.e. *Lipoptena* spp.), after the flies find the host, they lose the wings. Other species (i.e. *Melophagus ovinus*) have only vestigial, non-functional wings. Flying species have well-developed eyes, but in flightless species and in those which lose the wings, the eyes are rudimentary. All species have well-developed mouthparts (Russell et al. 2013). The most common species, *Melophagus ovinus* is 5-8 mm long, has a brown colour and a leather-like surface, with an indistinct abdomen and strong claws. *Hippobosca equina* is 10 mm long (Wall and Shearer, 1997).

Biology and life-cycle. Louse flies and keds (both the males and the females) are permanent blood-sucking parasites of birds and mammals, including a variety of domestic species. In keds (*M. ovinus*), the females mate in 24 hours after they emerge from the pupae. The females are larviparous, and they lay the first larva 12-13 days after mating. Further on, the females lay additional larvae (one each time) every 7-8 days for all their life (which usually lasts 4-5 months). Overall, a female *M. ovinus* will produce around 15 larvae before its death. The larvae undergo two moults in the uterus of the female ked, and they are laid as third stage larva in the fleece of the sheep. The larva becomes a pupa in 6 hours after its deposition. The pupa stage lasts for 20-26 days. The life cycle is going on around the whole year, but development times are longer during the winter (Wall and Shearer, 1997; Russell et al. 2013). The sheep keds are parasitic

mainly on sheep but also on mouflons and goats. They feed every 36 hours, each blood meal being around 3-15 mg (Deplazes et al. 2016). The life cycle is similar in principle with the one described for *M. ovinus*. *Hippobosca equina* feeds mainly on horses, but can be found occasionally also on cattle (Wall and Shearer, 1997). *Hippobosca longipennis* feed mainly on dogs, but it has been recorded also on domestic cats and wild carnivores (foxes, mongooses, civets, hyenas, wild felids) (Lloyd 2002).

Epidemiology. *Melophagus ovinus* has a worldwide distribution. It is still locally common in Europe. Transmission between sheep is via direct contact. *Hippobosca* spp. are more common in regions with warmer climate. In dogs, *H. longipennis* is very common in tropical regions. *Lipoptena cervi* is very common on deer in Europe and North America.

Disease. The most important clinical sign in sheep infested with keds is pruritus and anxiety, with lesions secondary induced by itching: wool loss and dermatitis but also economic losses. Allergic reactions have been also documented (Deplazes et al. 2016).

Vectorial role. *Melophagus ovinus* is the vector of *Trypanosoma melophagium*, a non-pathogenic kinetoplastid. *Hippobosca longipennis* is a vector of *Acanthocheilonema dracunculoides*.

Diagnosis. *Melophagus ovinus* is found mainly in the fleece of the neck and chest area, and the lateral parts of the abdomen (Deplazes et al. 2016). *Hippobosca longipennis* and *Lipoptena cervi* have the tendency to “dive” in the

fur and hide, or, in the case of *Hippobosca*, even to fly, but only on short distance.

Treatment and control. Pour-on insecticides are effective against keds in sheep. The therapeutic options against *Hippobosca longipennis* are poorly known.

3.4. Myiasis causing Diptera

Myiasis are parasitic conditions of humans and animals, often with severe clinical picture, even death, caused by larvae of various insects, known as maggots or grubs. These larvae feed on live or necrotic tissues of their host which are most commonly mammals and birds and more occasionally reptiles or amphibians (Wall and Shearer 1997).

According to the location on/in the host's body, myiasis are classified in cutaneous, dermal, subdermal, ocular, nasopharyngeal, gastrointestinal and urogenital. Another classification, which is more relevant for understanding their biology, uses the type of parasite-host interaction. According to this system, the myiasis can be obligatory, facultative or accidental (Wall and Shearer 1997). Agents of **obligatory myiasis** cannot complete their life cycle without a host. All Oestridae are obligatory parasites (table 6). **Facultative myiasis** are produced by species which can use either a living host or dead organic matter for their larval development. The agents of facultative myiasis can be further subdivided into **primary agents of facultative myiasis** or **secondary agents of facultative myiasis** (table 6).

Table 6. Main agents of myiases in animals

Family/Subfamily	Genus	Location	Type	Affected hosts
Oestridae/Oestrinae	<i>Oestrus</i>	nasal cavities	obligatory	sheep, goats
	<i>Rhinoestrus</i>	nasal cavities	obligatory	equids
	<i>Cephenemyia</i>	nasal cavities	obligatory	cervids
	<i>Pharyngomyia</i>	nasal cavities	obligatory	cervids
	<i>Cephalopina</i>	nasal cavities	obligatory	camels
Oestridae/Gasterophilinae	<i>Gasterophilus</i>	stomach, intestines	obligatory	cervids
Oestridae/Hypoderminae	<i>Hypoderma</i>	subcutaneous	obligatory	cattle, cervids
	<i>Przhevalskiana</i>	subcutaneous	obligatory	goats
Oestridae/Cuterebrinae	<i>Dermatobia</i>	subcutaneous	obligatory	various, also humans
	<i>Cuterebra</i>	subcutaneous	obligatory	rabbits, rodents
Calliphoridae	<i>Cochliomyia</i>	skin, orifices	facultative*	various, also humans
	<i>Chrysomya</i>	skin, orifices	facultative*	cattle, humans, others
	<i>Lucilia</i>	skin	facultative	sheep, others
	<i>Calliphora</i>	skin	facultative	sheep, others
	<i>Phormia</i>	skin	facultative	various
	<i>Protophormia</i>	skin	facultative	sheep, others
	<i>Cordylobia</i>	subcutaneous	obligatory	dogs, humans, others
Sarcophagidae	<i>Wohlfahrtia</i>	skin, orifices	obligatory	sheep, various others
	<i>Sarcophaga</i>	skin, orifices	facultative	various
Muscidae	<i>Musca</i>	skin, orifices	facultative	various
Fanniidae	<i>Fannia</i>	skin, orifices	facultative	various

*with the exception of *Cochliomyia hominivorax* and *Chrysomya bezziana* which are both obligatory parasites

In species causing primary facultative myiases, parasitism is their primary way of living and larval development on dead organic matter is only occasional. Such species are able to initiate myiasis on otherwise healthy hosts, with intact skin. In contrast, agents of secondary facultative myiases are predominantly saprophages which can occasionally invade pre-existing infestations caused by primary agents. They cannot initiate myiasis. Last but not least, there are a number of species being able to cause **accidental myiases**, but only on very rare occasions (Wall and Shearer 1997).

All agents of myiases are taxonomically included in the superfamily Oestroidea which has three families of veterinary importance: Oestridae (nasal bot flies, stomach flies, warble flies), Calliphoridae (blow flies, screw-worm flies) and Sarcophagidae (flesh flies).

3.4.1. Blow flies and screw-worm flies (Calliphoridae)

Blow flies and screw-worm flies (Calliphoridae) are a large group of flies, with worldwide distribution responsible for myiasis in humans and animals.

Taxonomy. Calliphoridae is a diverse family of flies, comprising more than 1000 species in over 150 genera. Not all the species are parasitic, the vast majority feeding on carrion and not on live animals. Around 80 species have been recorded as agent of myiasis in humans and animals, the most important genera (species) being ***Cochliomyia*** (*C. hominivorax*, *C. macellaria*), ***Chrysomya*** (*C. bezziana*, *C. megacephala*, *C. rufifaces*, *C. albiceps*), ***Lucilia*** (*L. sericata*, *L. cuprina*, *L. caesar*), ***Calliphora*** (*C. vomitoria*, *C. vicina*), ***Protophormia*** (*P. terraenovae*), ***Phormia*** (*P. regina*) and ***Cordylobia*** (*C.*

anthropophaga) (table 6) (Russell et al. 2013).

Morphology. Family Calliphoridae includes medium to large dipterans, with a metallic colour in adult flies. Genus *Cochliomyia* includes green to violet-green blowflies with short palps and three prominent black longitudinal stripes on the thorax. Species in genus *Lucilia* have a green coloration (figure 107) and those in genus *Calliphora* are blue with a black thorax. *Chrysomya* flies are green to bluish-black. Adults of *Phormia* and *Protophormia* are dark blue to black. The adults of *Cordylobia* (figure 108) are large flies and, unlike in other Calliphoridae, the body does not have a metallic colouration but it is rather yellow-brown to red-brown (Wall and Shearer 1997; Russell et al. 2013).

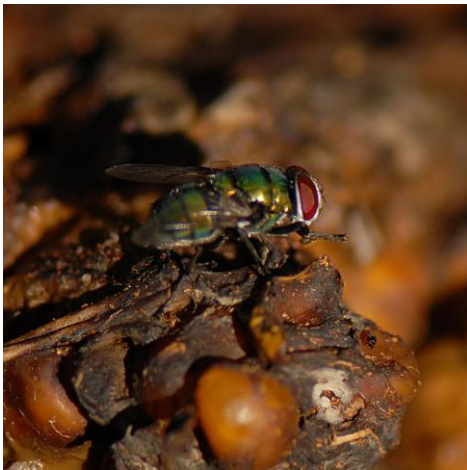


Figure 107. Adult *Lucilia* sp. resting on human feces (photo Andrei D. Mihalca)

Morphologically, also the immature stages are important as they are the ones found on animals. Eggs are usually small, oval-elongated and whitish. Larvae are

legless, worm-like, whitish or light yellowish in colour, and varying in size from few millimetres to more than one centimetre, according to the species and stage, with L1 the smallest and L3 the largest. As L3 are close to detachment, they usually become darker. All larvae have at their posterior end spiracles, which are usually dark brown. In some species the larvae have spines (*Cochliomyia hominivorax*, *Chrysomya bezziana*), in other they are hairy (various other *Cochliomyia* and *Chrysomya*), and in other they are smooth (*Lucilia*, *Calliphora*) (Russell et al. 2013).



Figure 108. Adult *Lucilia* sp. resting on human feces (photo Andrei D. Mihalca)

Biology and life-cycle. Most Calliphoridae breed principally on carrion. The species responsible for myiasis are usually facultative agents. Only two species are obligatory agents of myiasis: *Cochliomyia hominivorax* and *Chrysomya bezziana* (Russell et al. 2013).

Although there are certain characteristics for each species, the general life cycle of all Calliphoridae is largely similar. All species are oviparous and lay the eggs in wounded or infected skin of homothermous hosts. One notable exception is *Cordylobia anthropophaga* which lays the eggs on sandy ground. The larvae feed on the host's tissues and cause traumatic or cutaneous myiasis. There are three larval instars. The fully developed L3, the larvae leave the host, drop to the ground and become pupae. Adults which emerge from the pupae are free-living (Wall and Shearer 1997).

In the case of *Cochliomyia hominivorax*, the eggs are deposited at the edges of open wounds, but also in orifices such as the nostrils, eyes, anus, mouth, ear or vagina of a great variety of hosts (virtually all warm-blooded animals, including livestock, wild animals and humans). They also deposit eggs in the navels of new born calves or in minute wounds produce by tick bites. Females of *Cochliomyia macellaria* lay their eggs in carrion but also in infected wounds or at the level of pre-existing myiasis (Wall and Shearer 1997).

Chrysomya bezziana are obligatory parasites. They never infest carrion. The females lay the eggs at the edge of pre-existing wounds but also in orifices (Wall and Shearer 1997).

Genus *Lucilia* includes various species of which two are agents of primary myiasis. In *Lucilia sericata* and *Lucilia cuprina*, the females lay eggs in the fleece of sheep. Larvae hatch and feed on the superficial epidermis or necrotic

tissue, but also on healthy tissues, inducing primary myiasis (Wall and Shearer 1997).

In genus *Calliphora* the females lay the eggs in pre-existing wounds, acting mainly as agents of secondary myiasis in livestock but also other domestic and wild animals (Wall and Shearer 1997).

Cordylobia anthropophaga lays the eggs in sandy substrate, usually on soil with urine and feces, in shade, during early morning or late evening. The larvae hatch in 1-3 days and have "questing" behaviour, attaching to host passing in their vicinity which they detect by a sudden rise in temperature and CO₂ concentration. After larvae attach to the host, they burrow under the skin where they develop in few days. Typical hosts are dogs, rats and humans (Wall and Shearer 1997).

Epidemiology. Myiasis caused by Calliphoridae have a worldwide distribution, but each species has a more or less specific range. In tropical areas, myiasis produced by Calliphoridae occur year round, while in temperate regions they are seasonal and are generally restricted to the summer season.

Cochliomyia hominivorax and *C. macellaria* are distributed in southern USA, Mexico, Central America and South America. Due to successful biological control using sterile males, *Cochliomyia hominivorax* was efficiently controlled in various parts of the Americas. However, recently, the parasite has been accidentally introduced to North Africa from where it continues to spread south

(Wall and Shearer 1997). Species of genus *Chrysomya* are found only in the Old World, mainly Africa and Asia (Wall and Shearer 1997).

Lucilia sericata is the most important agent of sheep myiasis in Europe while *Lucilia cuprina* is found in Africa and Asia and has been introduced to Australia. In Europe, they may have up to three-four generation per summer. The risk is increasing with the flock size (Wall and Shearer 1997).

Species of *Phormia* and *Protophormia* prefer cooler climates, and they are the dominant agents of myiasis at northern latitudes in Europe (Wall and Shearer 1997).

Certain breeds of sheep are specifically sensitive to infestation by cutaneous myiasis, mainly due to anatomical particularities (i.e. Merino sheep or fat-tailed sheep breeds are sensitive to myiasis produced by *Lucilia*) (Deplazes et al. 2016).

Disease. The diseases produced by blow flies and screw-worm flies have some particular aspects. The screw-worm myiasis (produced by *Cochliomyia hominivorax* and *Chrysomya bezziana*) are traumatic myiasis affecting the skin but also the underlying tissues. Usually screw worm infestation start on pre-existing wounds (scratches, bites from other arthropods, including ticks, castration wounds, dehorning wounds).

Females of *Lucilia* lay their eggs (figure 109) in areas which sufficiently moist (fleece soiled by feces, urine, mud) like the back or flanks. Larvae can develop on the skin without producing lesions, or

they can penetrate through small wounds. The larvae of *Lucilia* produce proteolytic enzymes and feed on the epidermis, wound exudate but also on necrotic tissue. Infested sheep are (Deplazes et al. 2016).



Figure 109. Eggs of *Lucilia* in the fleece of a sheep (photo Andrei D. Mihalca)

Infested sheep are restless and have the tendency to remove the larvae from the affected areas by biting and scratching. In the affected areas, there is hair loss and wounds with larvae become clearly visible. Lesions consist of exudative dermatitis and dermatonecrosis, often with a bad smell. Often the lesions are infected with bacteria. As *Lucilia* larvae produce high quantities of ammonia, this can be toxic and mortalities of up to 10% were reported as a result of intoxication (Deplazes et al. 2016).

Facultative primary or secondary myiasis affect also other hosts, particularly weak animals, injured animals in decubitus or healthy animals with wounds (post-surgery or traumatic) (figure 110).



Figure 110. Ocular myiasis in a dog following a three-day decubitus because of a leg injury (photo Andrei D. Mihalca)

The furuncular myiasis caused by *Cordylobia anthropophaga* (also known as the Tumbu fly) is common in dogs in sub-Saharan Africa and is characterized by the presence of nodules over the lateral and dorsal parts of the body. Sometimes the nodules present in the middle a small opening where the larva will emerge. Former nodules are also visible as slightly indurated areas, with a central crust. Puppies are particularly affected (figure 111).

Diagnosis. Cutaneous myiasis are easy to diagnose, but when larvae are located in orifices, a closer examination is required. Specific identification of larvae requires entomological expertise. The subcutaneous myiasis produced by *Cordylobia* requires gentle pressure on the nodules (preferably on those which have already a central opening) and removal of larvae (figure 112).

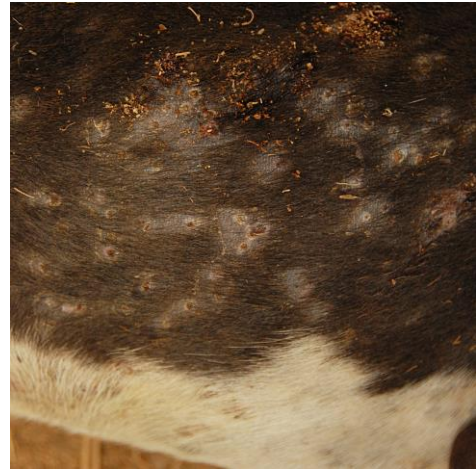


Figure 111. Furuncular myiasis produced by larvae of *Cordylobia anthropophaga* (photo Andrei D. Mihalca)



Figure 112. Removal of *Cordylobia anthropophaga* larva from the nodule (photo Andrei D. Mihalca)

Treatment and control. In sheep with myiasis produced by *Lucilia*, dips or sprays with insecticides are recommended in affected flocks. Injectable macrocyclic lactones are also effective and also provide several weeks of protection against further infestations. If lesions are severe, they should be treated also by mechanical

cleaning (larvae and necrotic tissue) and disinfection (Deplazes et al. 2016).

3.4.2. Flesh flies (Sarcophagidae)

Flesh flies are a diverse family, most of the species having no medical importance. They have a worldwide distribution

Taxonomy. The family includes more than 2000 species in 400 genera, of which only one genus has a true medical importance. Genus *Wohlfahrtia* includes several species: *W. magnifica* (Europe, Middle East, Asia), *W. vigil* (North Africa), *W. opaca* (all Holarctic region) and *W. nubia* (Africa and Middle East) (Russell et al. 2013). Genus *Sarcophaga* (figure 113) (*S. carnaria*) has a minor medical and veterinary importance.



Figure 113. Adult fly of genus *Sarcophaga* (photo Andrei D. Mihalca)

Morphology. The Sarcophagidae are medium to large sized flies, lacking the metallic aspect of Calliphoridae. They are generally grey with three black stripes on the dorsal part of their thorax.

Adults of *W. magnifica* are large flies (8-14 mm in length) with long black legs. The abdomen has characteristic patches on the dorsal surface (Russell et al. 2013).

Biology and life-cycle. Flies of genus *Wohlfahrtia* are obligate agents of myiasis. Females are lay 120-170 first stage larvae on the hosts in wounds or on intact skin, close to natural orifices. They feed with the local tissues, aggravating the wound which attracts more females to lay larvae.

In ca. 1 week, the L1 moult to L2 and L3 and they detach from the host, falling to the ground where they become pupae. Adults which develop from pupae are mostly nectarivorous (Wall and Shearer 1997; Deplazes et al. 2016).

Epidemiology. The local prevalence of sheep myiasis caused by *W. magnifica* is variable reaching up to 40% in certain flocks during the summer (Deplazes et al. 2016).



Figure 114. Genital myiasis produced by *W. magnifica* in a ram from Romania (photo Andrei D. Mihalca)

Disease. The most common location of lesions caused by larvae of *W. magnifica* are the genitals, mostly in rams, but also in ewes. The lesions consist in massive destruction of tissues with high number of larvae (figure 114). Occasionally, lesions are found also in other body parts, like the ears (figure 115).



Figure 115. Auricular myiasis in a ewe from Romania (photo Andrei D. Mihalca)

Diagnosis. It is easily achievable by observation of larvae in the lesions. Species identification requires medical entomology expertise.

Treatment and control. Similar to blow flies.

3.4.3. Nasal bot flies (Oestrinae)

Nasal bot flies are obligatory parasites developing in the nasal and pharyngeal passages of ungulates worldwide (Russell et al. 2013).

Taxonomy. Subfamily Oestrinae includes 34 species in 9 genera. The

most important genus is *Oestrus* (with the well-known species *O. ovis*) causing the nasal oestrosis in sheep and other small ruminants. Other genera include *Rhinoestrus* (in equids and large African mammals), *Cephenemyia* (in deer) and *Cephalopina* (in camels) (Wall and Shearer 1997; Russell et al. 2013).

Morphology. Adults flies (figure 116) are greyish in colour, 10-12 mm in length, with black spots on the abdomen, a broad head with small eyes (Wall and Shearer 1997).



Figure 116. Adult *Oestrus ovis* (photo David Modrý)

The larvae are white and vary in size according to the stage. L1 are small, 1 mm in length; L2 are 4-12 mm and L3 17-28 mm long. When L3 are in their late stage, they become brownish with dark, transverse bands (Wall and Shearer 1997; Deplazes et al. 2016).

Biology and life-cycle. The females of *Oestrus ovis* are larviparous. They lay around 25 L1 at a time directly in or on

the nostrils of sheep, during flight. A female can produce 500-1000 larvae during her life. After deposited, L1 start to crawl through the nasal cavities and attach the mucosa, feeding with mucus and desquamated epithelial cells. Before moulting to L2, they migrate to the frontal sinuses through the ethmoid process. The final moult to L3 occurs also at this site. Mature L3 migrate back from the frontal sinuses to the nasal cavities from where they are sneezed out, reach the ground and become pupae. All over, the larval development takes around 1 month and the pupal period 2-6 weeks. In areas with temperate climate, *O. ovis* has only one generation per year, and, to avoid emergence of adults in the same season, L1 enter into diapause and stop their development until next spring. Hence, the overwintering takes place in the host, and clinical signs occur mainly during the cold season (Wall and Shearer 1997; Deplazes et al. 2016).

Epidemiology. *Oestrus ovis* has a worldwide distribution, with large prevalence in areas with high sheep densities (Deplazes et al. 2016).

Disease. When larvae are laid, sheep are agitated and show signs of local foreign body by rubbing their nose to various objects and by shaking their head. Larvae located in the nasal cavities and sinuses (figure 117) are permanently irritating the mucosa and cause rhinitis with sneezing, nasal discharge (figure 118), coughing, and in severe cases dyspnoea. Severe case result in chronic, debilitating disease with weight loss,

anorexia and even death, following complications (i.e. bacterial infection).



Figure 117. L3 of *Oestrus ovis* in the nasal cavities of a sheep (photo David Modrý)



Figure 118. Mucous nasal discharge in a sheep with oestrosis (photo Andrei D. Mihalca)

In general, sheep are more susceptible to oestrosis than goats. Humans can be also occasionally affected. Experimental trials have suggested that multiple infections can lead to an increased resistance, as a result of immunity.

Diagnosis. Clinical signs are indicative for oestrosis, but demonstration of the presence of larvae in the nasal cavities is difficult in live animals. Specific treatment administration with ceasing of clinical signs is indicative for oestrosis. Sometimes, following treatment, larvae can detach and fall but their observation is a matter of chance. Post-mortem diagnosis is the most efficient. Serologic tests are developed but not commercially available.

Treatment and control. Injectable ivermectin and doramectin are very efficient (0.2 mg/kg). Treatment should be done in autumn or early winter (Deplazes et al. 2016).

3.4.4. Stomach bot flies (*Gasterophilinae*)

Stomach bot flies are obligatory parasites of the gastrointestinal tract of equids and other large mammals (i.e. elephants and rhinos), causing sometimes severe clinical signs.

Taxonomy. *Gasterophilinae* includes 18 species in 5 genera. Only genus *Gasterophilus* includes species of veterinary concern. The genus includes 9 species, of which the most important are: *G. intestinalis*, *G. haemorrhoidalis*, *G. inermis*, *G. nasalis*, *G. nigricornis*, and *G. pecorum*.

Morphology. Adult flies are large insects, 11-15 mm in length, with a body covered with dense yellowish hairs (figure 119).



Figure 119. Adult of *Gasterophilus* sp. (photo David Modrý)

The larvae have a spindle shape and a segmented body (figure 120). The front part of most segments is covered with 1-3 rows of small spines. The mouthparts consist of strong hooks which are used for attachment to the digestive mucosa and for feeding. The posterior part bears the spiracles, which are dark, paired organs. The mature L3 are 15-20 mm in length (Deplazes et al. 2016).

Biology and life-cycle. In the temperate regions, there is one generation per year, and larvae use the hosts for overwintering. However, in tropical regions, there are multiple generations per year. There are also slight variations of the life cycle according to the species of *Gasterophilus*. The adults have a very short life span (few days up to one week) (Deplazes et al. 2016). After ca. 20 h after emerging from pupae, females will visually and olfactory search for an equid host where they lay the eggs (figure 121) and glue them to the hair of the horse.



Figure 120. L3 of *Gasterophilus* sp. (photo David Modrý)

There are differences between the species regarding the preferred egg laying sites. inner surface of forelegs (*G. intestinalis*) (figure 122), hair of lips (*G. haemorrhoidalis*), cheeks (*G. inermis* and *G. nigricornis*), or mandibular space (*G. nasalis*). One species (*G. pecorum*) lays the eggs on vegetation.

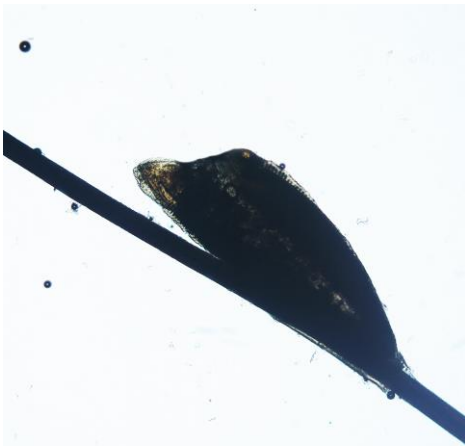


Figure 121. Egg of *Gasterophilus* sp. (photo Andrei D. Mihalca)



Figure 122. Eggs of *Gasterophilus intestinalis* on the inner part of the front legs (photo Andrei D. Mihalca)

In case of *G. intestinalis*, the horses lick the egg deposition site (or in the case of *G. pecorum* they ingest them when grazing) and L1 will hatch and penetrate the oral mucosa. In *G. inermis*, *G. nigricornis* and *G. nasalis*, the larvae hatch without the eggs being licked and actively migrate to the corners of the mouth and penetrate the oral mucosa. The migration is also different, according to the species.

In *G. intestinalis*, L1 penetrates the tongue mucosa and migrates to the distal part of the tongue where it moults to L2. L2 continues the migration through the pharynx and epiglottis and reach the cardiac part of the stomach where it moults to L3 (Deplazes et al. 2016).

In *G. haemorrhoidalis*, L1 starts the migration from the lips or the mouth mucosa, reaches the stomach as L2 and the rectum as L3 (Deplazes et al. 2016).

The migration of *G. inermis* starts as L1 in the skin near the corner of the mouth and the buccal mucosa, L2 and L3 eventually reach the rectum (Deplazes et al. 2016).

In *G. nasalis*, L1 migrate from the skin of the lips and gingival mucosa where they moult to L2. L2 reaches the proximal duodenum where they become L3 (Deplazes et al. 2016).

The L1 of *G. nigricornis* migrate from the skin near the corner of the mouth, through the buccal mucosa where they moult to L2. L2 migrates to the duodenum where they moult to L3 (Deplazes et al. 2016).

In *G. pecorum*, after the eggs are taken from plants, the L1 hatch and migrate through the mucosa of the lips, tongue and both the soft and hard palate where they moult to L2 which continues the migration via the tongue and pharynx to the cardial part of the stomach where they become L3 (Deplazes et al. 2016).

In general, the L1 stage remains for 3-4 weeks in various parts of the buccal cavity and the mature L3 are eliminated through the feces of the horse 8-10 months post infections. The pupae develop in the horse manure, from where the adults will emerge after 2-12 weeks (Deplazes et al. 2016).

Epidemiology. Gasterophilosis is a common parasitic disease of horses worldwide. Three species have become spread to all the continents (*G. intestinalis*, *G. haemorrhoidalis*, *G. nasalis*), while the others have a more restricted distribution, in general to the Old World (Deplazes et al. 2016). Due to

the specific life cycle, the disease in the temperate regions is highly seasonal, with infestation in late summer and clinical signs in the winter

Disease. The clinical picture depend on the level (intensity of infestation), with low (few larvae) and moderate (up to 100 larvae) per horse being generally asymptomatic. However, high numbers of larvae (100-1000) can produce severe clinical signs. The onset of severe forms is usually in the form of a severe stomatitis and glossitis, with consequent difficulties in prehention, mastication and deglutition. At a later stage, more into the cold season, the gastric or intestinal lesions (erosions, ulcers, necrosis, loss of glandular tissue, inflammations, fibrosis) are clinically characterized by inappetence, colic, cachexia. Perforations of stomach or intestine can occur, but these are rare events (Deplazes et al. 2016).

Unlike in other myiases, it seems that horses do not develop immunity against *Gasterophilus*, and even repeated infestations in old horses do not decrease in severity or intensity (Deplazes et al. 2016).

Diagnosis. Finding the eggs in the typical oviposition sites in the summer is the easiest way to anticipate the larval migration. Macroscopic examination of feces in late spring/early summer for the presence of mature larvae or pupae is also of diagnostic value. However, demonstration of larvae in the predilection organs (stomach, intestines, rectum) is rather difficult and requires endoscopy. In house serologic tests are also available (Deplazes et al. 2016).

Treatment and control. Macrocyclic lactones are the most effective way of chemical treatment against stomach bot flies. Two molecules are used in general via oral route (gel or paste) in horses: ivermectin and moxidectin. These are active against L2 and L3 and less against L1.

As pupae develop in feces, removal of horse dung is essential for preventing emergence of adults and for discontinuing the life cycle. Eggs can be also removed from the fur of horses in order to decrease the infestation pressure. Various repellents or fly masks are available to reduce the oviposition by females *Gasterophilus*.

3.4.5. Warble flies (*Hypoderminae*)

Warble flies are responsible for producing subcutaneous myiasis, especially in domestic and wild ruminants, representing an important problem worldwide.

Taxonomy. The subfamily includes 32 species in 11 genera. The only genera with veterinary importance are *Hypoderma* and *Przhevalskiana*. Three species of genus *Hypoderma* are more important: *H. bovis*, *H. lineatum* (both in cattle) and *H. diana* (in deer) (Wall and Shearer 1997). Genus *Przhevalskiana* (*P. silenus*) is parasitic in goats.

Morphology. Adult flies of genus *Hypoderma* are large flies (ca. 13-15 mm in length), described as having a bumble-bee appearance. The body is covered with dense reddish-yellow hair, with a light-dark pattern. The mouth

parts are small and palps are absent (Wall and Shearer 1997).

The larvae of *Hypoderma* are maggot-like, and vary in size according to the stage and species. The largest are the mature L3 (30 mm in length) while the L1 is very small (less than 1 mm in length). In L3, most of the body segments have on their ventral side two rows of well-developed spines and smaller spines on their dorsal side.

Biology and life-cycle. In general, these myiasis-causing insects are host-specific, with occasional exceptions. The life cycles of the two *Hypoderma* species parasitic in domestic animals follow some common patterns but are also different, mainly regarding the migration route.

In *H. bovis*, the adults are active from June to September (in Europe). Mating occurs immediately after the emergence of females. Mated females lay 300-600 eggs in the few days of their life, usually on the lower regions of the legs and lower body and glued, singly, to the hair. Eggs hatch in ca. 4 days, and L1 larvae penetrate the skin. Most larvae migrate via along the nerves to the spinal canal, where they are found ca. 4 months later. Other larvae seem to use also a different migration route which is not known. Larvae overwinter at this level. During early spring, larvae re-start their migration and after 9 months from oviposition they reach the subcutaneous tissue in the dorsal region, laterally to the midline. At this level, they moult to L2 and then, to L3. The nodules are later (after 1-2 more months) perforated by the L3. The mature L3 falls to the ground

and become pupa. The pupal stage lasts 3-10 weeks (Wall and Shearer 1997; Russell et al. 2013).

In *H. lineatum*, the adults are active from April to June. The females lay the eggs in batches of up to 15 eggs. After larvae penetrate the skin, they migrate between the fascial planes of the muscles and reach the wall of the oesophagus in ca. 4 months. Larvae overwinter at this level. All other events in the life cycle of *H. lineatum* are similar to *H. bovis* (Wall and Shearer 1997).

Hypoderma diana is active from May to June. The life cycle and migration route is similar to *H. bovis* (Wall and Shearer 1997). The life cycle and migration route of *Przhevalskiana silenus* seems to be local, with larvae penetrating the skin at the oviposition site where they remain and later form nodules (Deplazes et al. 2016).

Epidemiology. *Hypoderma bovis* and *H. lineatum* are present throughout the temperate regions on Europe, Asia, and North America. Generally, the two species overlap in distribution, but *H. bovis* is spread more to the north than *H. lineatum*. Various countries have successfully implemented national strategic program for the control of hypodermosis and now the disease in cattle is eradicated or almost eradicated in most of Europe. Prevalences in endemic areas can reach 100%, which was the situation also in Europe before the implementation of control programs. As immunity develops, usually the disease is more common and severe in young cattle (Russell et al. 2013; Deplazes et al. 2016).

Hypoderma diana in deer has a large distribution in the Palearctic region (Wall and Shearer 1997).

Przhevalskiana silenus is affecting goats in the Mediterranean region, with high local prevalences (even >50%) (Deplazes et al. 2016).

Disease. The most important effect of hypodermosis is the economic impact. This is caused by a significantly reduced milk production (10-15%) and growth due to disturbance by ovipositing females. Flying *H. bovis* significantly disturb the cattle. Those of *H. lineatum*, generally don't. Presence of larvae and their migration routes also cause significant amount of condemnation of various body parts (muscles, leather) during the slaughterhouse technologic flow (Russell et al. 2013).

When adult *Hypoderma* are ovipositing cattle display a "panic escape reaction" (also known as gadding). During this, cattle may suffer injuries by hitting fences or other objects on the pasture. Larvae in migration usually do not cause significant clinical signs, but the lesions can be locally severe, with heavily eosinophilic areas. The presence of larvae of *Hypoderma* in the subcutaneous tissue (figure 123) are responsible for the development of nodules which are clearly visible in the dorsal part of the animal, lateral to the middle line of the spine (Deplazes et al. 2013).

Destruction of large amounts of larvae in a very short time can produce anaphylactic reactions and even anaphylactic shock (Russell et al. 2013).



Figure 123. L3 of *Hypoderma diana* in the subcutaneous tissue of a roe deer (photo Andrei D. Mihalca)

Repeated contacts of cattle with *Hypoderma* produce partial immunity and resistance, with a significantly lower survival rate of L1 after the second infestation (Deplazes et al. 2016).

Diagnosis. The diagnosis of hypodermosis is easy when nodules are present on the back (clinical inspection or post-mortem visualisation). However, it is very important to diagnose the infestation in its early stages, while migrating larvae do not produce extensive damage. This is achievable by using various commercial serologic tests which are able to detect the antibodies 3-6 weeks post infestation (Deplazes et al. 2016).

Treatment and control. The success of strategic control measures demonstrate that hypodermosis is relatively easy to control. Macrocyclic lactones are highly efficient either as pour-on (eprinomectin 0.5 mg/kg; moxidectin 0.5 mg/kg; doramectin 0.5 mg/kg ivermectin 0.5

mg/kg) or injectable (ivermectin, doramectin etc.) (Deplazes et al. 2016).

3.4.6. Other agents of myiases and related species

Subfamily Cuterebrinae (within family Oestridae) includes 70 species in 6 genera. All are found only in the Americas. Two genera are of medical/veterinary importance. Genus *Cuterebra* includes cutaneous parasites of rodents and lagomorphs (rarely also dogs and cats), causing hypodermic nodules. The females of *Cuterebra* lay their eggs on the ground near the nest or burrows of their hosts and picked-up by the passing hosts. Subsequently the larvae actively penetrate the skin and migrate through the subcutaneous tissue (Wall and Shearer 1997).

Genus *Dermatobia* includes a single species, *D. hominis* which is parasitic in various wild and domestic hosts, including humans. The life cycle is extremely unusual. Adult females of *Dermatobia* capture other insects (usually mosquitoes or muscid flies) and glue the eggs (ca. 30) to their body where they incubate. When this carrier insect will land on a potential host, the larvae will hatch and larvae will penetrate the skin and locally form subcutaneous nodules, without migration. *Dermatobia* is an important myiasis of cattle in Central America (Wall and Shearer 1997).

Family Muscidae (also known as house flies) are a very rich family, with more than 4000 species. The most important genus is *Musca*, with several species of veterinary importance: *M. domestica*, *M.*

autumnalis, *M. larvipara*, *M. sorbens*, or *M. vetustissima*. They are rarely causing myiasis but they are important mechanical or biological vectors for various pathogens. It has been demonstrated that flies of genus *Musca* mechanically transmit viruses (poliomyelitis, infectious hepatitis), bacteria (*Salmonella*, *Shigella*, *Escherichia*, *Staphylococcus*, *Bacillus anthracis*, *Mycobacterium* spp., etc.). House flies are also biological vector for various nematodes (*Habronema*, *Thelazia*) or intermediate host for cestodes of poultry (e.g. *Choanotaenia*) (Russell et al. 2013).

Other species of Muscidae include the biting species of genus *Haematobia* (figure 124) which are important pests of cattle and horses in Europe and are mechanical vectors for various diseases of livestock (Deplazes et al. 2016).

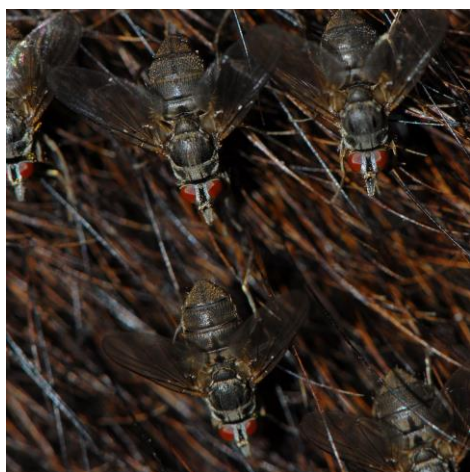


Figure 124. *Haematobia* sp. feeding on a horse (photo Andrei D. Mihalca)

Family Fanniidae is a small family (ca. 260 species). The only important genus is genus *Fannia* which includes several species of medical importance: *F. canicularis*, *F. scalaris*, *F. benjamini*, etc. They are not causing myiasis but are considered a permanent nuisance for humans and livestock, especially poultry (Wall and Shearer 1997; Russell et al. 2013).

3.5. Other dipterans of veterinary importance

3.5.1. The bee louse (*Braula coeca*)

The bee louse is a pest of honeybees worldwide, with less impact than the bee-mite, *Varroa destructor*.

Taxonomy. The single species of veterinary importance is *Braula coeca*. Other species have been also described (e.g. *B. schmitzi*, *B. pretoriensis*) but their taxonomic status is still debated (Bailey and Ball 1991).

Morphology. *Braula coeca* is a small (1.5 mm) wingless insect (figure 125) with a reddish-brown colour. It can macroscopically resemble to *Varroa destructor*, but a closer inspection reveals a typical insect morphology. The body is covered with spine-like hairs. Above the antennae, the adults have eyes. The thorax is very short. The eggs are white and oval. The larvae are maggot-like and very small (they cannot be detected by a simple visual inspection). The pupae are white or yellowish.



Figure 125. *Braula coeca*: general morphology (photo Andrei D. Mihalca)

Biology and life-cycle. *Braula coeca* is considered a commensal of the honey bee colonies. The adults are typically located on the head of the adult honey bees, mainly on the queens but also on the workers and drones. The preference for the queen was evolutionary explained by the fact that queens are the longest living bees, almost never leave the hive and receive food with a higher frequency compared to workers and drones. *Braula* will feed directly from the mouth of the bees, mainly when the bee is fed by another bee or when the bee feeds another bee (Bailey and Ball 1991). Females lay the eggs in the hive mainly on brood cappings. In 2-7 days, a larva will hatch from each egg. The larva will dig tunnels in the wax forming the cappings, feeding with the honey and pollen and possibly also with wax. The tunnels pass thorough several cells and expand as the larvae grow. There are three larval stage followed by a pupa. All pre-adult development takes place in the tunnels (Bailey and Ball 1991).

Epidemiology. Due to the intensive intense measures implemented for the control of *Varroa destructor*, the populations of *Braula coeca* have been dramatically reduced. In the past, it was an ubiquitous inhabitant of honey bee colonies, with almost worldwide distribution.

Disease. *Braula coeca* presence in the honey bee colony is considered of minimal economic importance as they do not typically harm the bees. There is some indication that *B. coeca* can induce regurgitation in the bees followed by feeding on this material. The damage to the cappings has only aesthetic importance and is not considered to have an economic impact.

Diagnosis. Presence of adult parasitic insects can be noticed on a closer visual inspection, followed by microscopic confirmation. Presence of tunnels in the cappings is also characteristic for the presence of *Braula*.

Treatment and control. Usually there is not control measure recommended for the *Braula* infestation. Most products used against *Varroa* are also effectively eliminating *Braula*.

3.5.2. Other groups

Family Drosophilidae (subfamily Steganinae) includes various genera of which only few are of medical and veterinary importance. Some species feed on eye secretion and can be nuisance for animals and humans but also vectors. *Phortica variegata* is the vector of *Thelazia callipaeda* (Russell et al. 2013).

4. Crustacea

Crustaceans are a large group of arthropods which include a great variety of species, most of them having a free-living life and inhabiting aquatic environments. Examples include: crabs, crayfish, lobsters, shrimps, krill, copepods etc. There are also several other groups including phoretic species (barnacles), terrestrial groups (woodlice) and several parasitic groups.

The most important parasitic crustaceans belong to the following groups: **copepods** (mostly on marine but also on fresh water fish, but also on other hosts like cnidarians, annelids, molluscs, other arthropods, echinoderms, ascidians, amphibians or marine mammals), **branchiurans** (on marine and fresh water fish, rarely on amphibians), **amphipods** (on cetaceans), **isopods** (parasitic in fish and in other crustaceans), **cirripedians** (parasitic in crabs), **ascothoracicans** (parasitic on echinoderms and cnidarians), **tantulocaridans** (parasitic on other crustaceans) and **pentastomids**, also known as tongue worms (parasitic in amphibians, reptiles, birds and mammals) (Bush et al. 2001).

4.1. Pentastomida

Also known as the tongue worms, this group has an uncertain taxonomic position. In various textbooks Pentastomida is considered to be a separate phylum, in others they are

considered as part of Arthropoda, with possible affinities to Crustacea, as it was genetically demonstrated. We will follow here this opinion.

This is a relatively small group, with little over 100 known species, exclusively parasitic, dioecious (with separate sexes). All tongue worms are obligatory heteroxenous parasites of the respiratory tract of a wide variety of hosts. The vast majority of adult pentastomids are parasitic in the lungs of reptiles (mostly snakes). Few species are found in the air sacs of marine birds and the nasal cavities and pharynx of canids and felids. Additionally, there is only one known species parasitic in amphibians. Larval and nymphal forms develop in various intermediate hosts, mostly vertebrates (Bush et al. 2001).

4.1.1. The canine tongue worm (*Linguatula serrata*)

Linguatulosis is a zoonotic disease affecting primarily dogs, with a cosmopolitan distribution, but generally with rare occurrence.

Taxonomy. The only pentastomid species of veterinary concern is *Linguatula serrata*, parasitic as adult in the nasopharyngeal space in dogs, wild canids and rarely also in cats.

Morphology. The adult worms are dorsoventrally flattened, worm like and tongue shaped. The males (2 cm in length) are significantly smaller than

females (up to 13 cm). The body has a segmented appearance, but this is only superficial, forming annuli (or pseudosegmentation). The anterior end (known as the head) has one mouth opening and four more fake openings, each bearing a hook (hence the name *Pentastomida* meaning “five mouths”) (figure 126). The body surface is covered by a cuticle containing chitin (Bush et al. 2001; Deplazes et al. 2016).

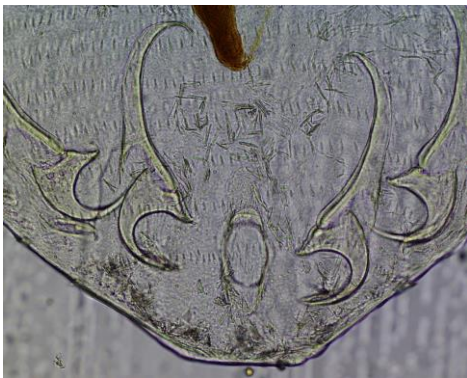


Figure 126. Anterior end of *Linguatula serrata* (photo Andrei D. Mihalca)

Biology and life-cycle. The life cycle is heteroxenous. Definitive hosts are usually the canids (domestic dogs, wolves, foxes, etc.) and rarely other carnivores which harbour the adults in the nasal cavities and pharynx. At this level, after mating with a male, the females lay numerous eggs which contain a primary larva, immediately infective to the intermediate host, usually an herbivore (rodents, lagomorphs, ruminants, camels, other herbivores). The eggs are eliminated usually through the feces of the definitive host, or through the nasal secretion. After the larvated egg is

ingested by a suitable intermediate host, the larva hatches in the intestine, penetrates the intestinal wall, and migrates to various internal organs (most commonly lymph nodes, but also lungs or liver) where it moults several times (up to 10) to the final nymphal stage (figure 127). The definitive hosts will become infected after ingesting organs of an intermediate host containing nymphs. The life span of adult females in the nasopharynx of the definitive hosts is ca. 2 years (Deplazes et al. 2016).

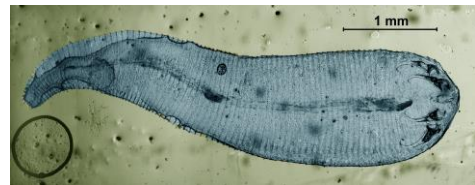


Figure 127. Nymph of *Linguatula serrata* extracted from the lungs of a naturally infected pet guinea pig (photo Andrei D. Mihalca)

Humans can act both as dead-end intermediate or aberrant definitive hosts for *L. serrata*. As intermediate hosts, humans get the infection by ingesting eggs of *L. serrata* (but similarly, also eggs of other pentastomids) from contaminated food or water. This results in visceral pentastomiasis, which is usually asymptomatic. However, if humans eat raw organs from infected intermediate hosts, the mature nymphs will immediately migrate to the nasopharynx and cause severe pain at this level.

Epidemiology. Canine linguatulosis has a worldwide distribution. In Europe, it is present, but generally rare. Hot spots of

disease, with high prevalence in dogs and intermediate hosts were reported in several Asian countries, including Iran and India (Deplazes et al. 2016).

Disease. Adults of *L. serrata* (figure 128) feed with nasal mucosa and cellular debris. Also asymptomatic cases are not uncommon, usually the presence of tongue worms in the nasopharynx of dogs is associated with pain, nasal foreign body signs (sneezing, intense, even brutal scrapping, rubbing the nose to various objects), unilateral or bilateral epistaxis. Severe infestations, with the presence of parasites deep in the ethmoidal region are associated with nervous signs reminding of rabies.

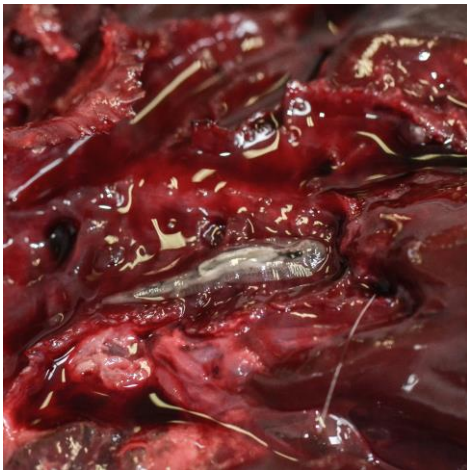


Figure 128. Adult female of *Linguatula serrata* in the nasal cavity of a naturally infected fox (photo Andrei D. Mihalca)

The presence of immature stages (larvae or nymphs) in the lymph nodes (figure 129) or various internal organs of intermediate hosts is usually asymptomatic.

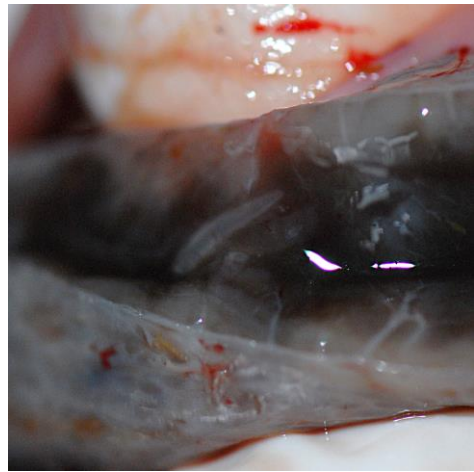


Figure 129. Nymph of *Linguatula serrata* in a mesenteric lymph node of a naturally infected goat (photo Andrei D. Mihalca)

Diagnosis. Dogs with patent infection shed in their feces the typical eggs (70 x 90 μ m, containing the primary larva), detectable by sedimentation techniques (Deplazes et al. 2016). In dogs parasitized only by males or only by unfertilized females, the eggs are absent in the feces. In intermediate hosts, the diagnosis is only post-mortem.

Treatment and control. There is no officially registered drug for the treatment of linguatulosis in dogs. However, macrocyclic lactones have been reported to be efficient. Limiting the access of dogs to raw organs is an efficient way of prevention.

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