# Chapter 3
# Parasites and Their World Records in Their Fight for Survival

**Heinz Mehlhorn**

**Abstract** Parasites are animals that enter plants, animals and humans – but are not welcome. Therefore they had to develop strategies for invasion and survival – outside and inside of hosts. For this purpose they developed amazing, often unbelievable skills during evolution. Thirteen of them are presented in this chapter showing that they are fit for the future thus threatening mankind, if there are no precautions in the future.

## 3.1 Introduction

In their fight for survival parasites depend absolutely on their ability to adapt themselves to the life cycle, behaviour, food and physiology of peculiar hosts and on their capacity to create sophisticated ways of host finding. Since all these tasks needed huge numbers of trials, evolution supported only the "winners" and suppressed as "losers" all less well-adapted specimens. Therefore it is not astonishing that these winners developed admirable skills that are listed as top records in the scorebook of nature being often unbelievable when compared to the range of human skills. However, the fight for survival is never finally decided, especially not for those parasites that may harm the health of humans and animals, since human science declared war on these "beasts" that may endanger human survival on earth. We are now in round 11 out of 12 in the fight for survival – nothing has been decided, since vector-transmitted viruses lurk everywhere in a globalized world. The sudden outbreak of the West Nile virosis in the USA (transmitted by mosquitoes), the unexpected outbreak of Blue Tongue virosis in 2006 in Central Europe (transmitted by Ceratopogonid midges), or the pandemics of the virus-based disease SARS (severe acute respiratory syndrome), "bird flu" and "pig flu" prove that we live on very thin ice or on a still silent volcano.

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## 3.2 *Giardia lamblia*: Twins in One Body with a Giant Holdfast System

***Twofold keeps better***
***(Tailor's wisdom)***

Greek mythology reports that at the beginning of social life on earth ancestors of humans lived as happy hermaphrodites uniting both sexes in one body. After human disobedience against divine rules this totipotent organism was divided by judgement of the gods into male and female organisms punished with the endless "pain" of reciprocal attraction. *Giardia* – named after the famous Italian scientist Alfredo Giardi (1846–1908) – is such an original organism in eternal inner peace.

*Giardia* species, races or strains – or whatever definitions will be used in future – are worldwide able to infect many hosts and act as **opportunistic agents of diseases** introducing severe symptoms of diarrhoea in immunosuppressed hosts, while none or low-graded ones occur in immunocompetent hosts. *Giardia* specimens are flagellated protozoans, which in evolution apparently once had missed a cell division, so that they have lived since then as a double organism with a longitudinal symmetry: both the left and right side of the drop-shaped cell each contain one genetically identical nucleus and four flagella arranged in an identical pattern (Fig. 3.1a–c). Their survival strategy follows two pathways: (1) The 10–20-µm long trophozoite is strongly attached with the help of its giant ventral holdfast system (disc) at the intestinal cells of the hosts (Fig. 3.1b) and feeds via food vacuoles at its dorsal surface (Fig. 3.1c). (2) The 15–20-µm sized, ovoid-shaped cyst is able to survive outside of the host due to its strong wall. The cell organelles of the cyst are doubled, since already four nuclei are present, so that immediately after the cyst has reached the intestinal lumen of a new host, two new trophozoites may emerge from each cyst. These trophozoites become attached by means of their ventral sucker so tightly at the surface of the intestinal cells, that the permanent intestinal compressions during food transportation do not detach them. As soon as they have left their attachment point, deep depressions become visible at the surface of the host cells (Fig. 3.1b).

**Records of *Giardia***

1. ***Living sites***: inside and outside intestines
2. ***Stages***: Flagellated trophozoites, cysts
3. ***Size***: 15–20 µm
4. ***Characteristics***: all organelles are present at least in double feature, eight flagella, ventral disc
5. ***Reproduction***: Longitudinal fission
6. ***Hosts***: Worldwide occurrence in hundreds of millions of animals and humans
7. ***Transmission***: Orally by uptake of cysts from faeces of hosts, zoonotic activity
8. ***Prophylaxis***: Avoid human and animal faeces
9. ***Therapy***: Metronidazole

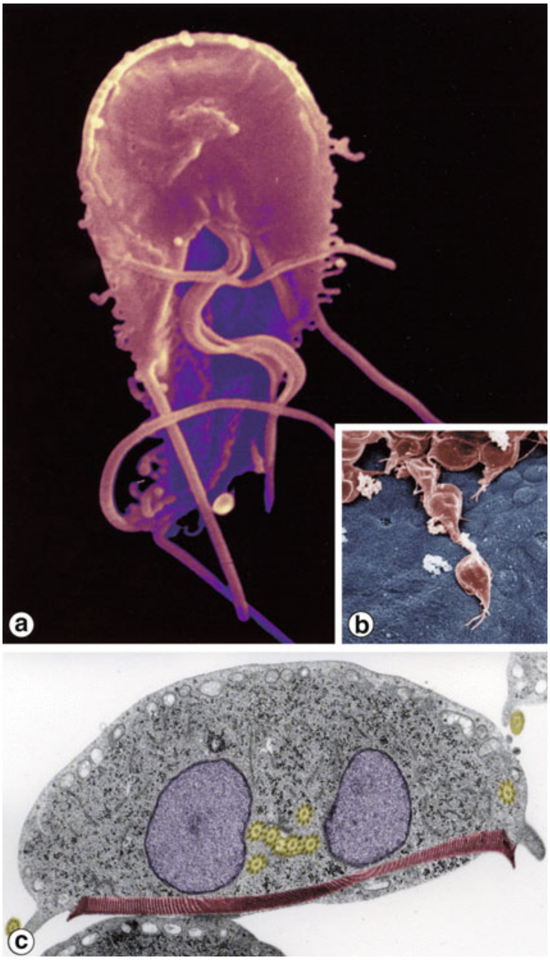

**Fig. 3.1** *Giardia lamblia* (stages from humans and animals) – Transmission (TEM) and scanning (SEM) electron micrographs. (**a**) Ventral side (SEM) (**b**) Dorsal side of attached stages. Note depressions at formerly parasitized host cells. (**c**) TEM of a cross section showing the two identical nuclei, the stiff proteins of the ventral sucker and the dorsal food vacuoles

## 3.3 *Trypanosoma* and *Leishmania* Stages: The Inventors of the Cloak of Invisibility

***A life undercover avoids detection***
***(Spy's wisdom)***

In the German world of sagas a blond, blue-eyed hero named Siegfried snatched a cloak of invisibility from the potent dwarf Alberich who watched over an enormous treasure. This cloak of invisibility enabled Siegfried to perform further acts of heroism.

A similar system of invisibility was developed by single-flagellated protozoans of the genera *Trypanosoma* and *Leishmania*, which live as parasites in the blood and/or inside tissues of man and animals and thus are constantly attacked by the famous and mighty immune system of the hosts, if they are recognized. In order to block such attacks these parasites have developed a protective shield on their cell membrane – a **surface coat** – which makes them invisible to the deadly arrows (= antibodies) of the immune system. However, since the host's defence is able to learn and thus produces "sharper arrows" after contact with the invaders, the latter change their shield during each division, when another of nearly 1,000 genes becomes active and produces another variation of the surface coat (layer of mucopolysaccharides) in order to hide perfectly the presence of the aggressors. Therefore these parasites are the "winners" in the struggle for life and pose severe problems to the relatively young species *Homo sapiens*, while African cattle and other ruminants have made their "peace" with the invaders, which live there at reduced reproductive rates in a surviving and rather untouched host.

Trypanosomes have developed a peculiar flagellum, which is attached to the surface of the cell (Fig. 3.2a) thus enabling the parasites to swim in the rather viscous blood. The *Leishmania* species have reduced the flagellum of intracellular stages to a stump, which does not overtop the surface while being anchored in a depression. Only the so-called promastigote stages in vectors have retained their free projecting flagellum (Fig. 3.2b). With respect to their non-intestinal parasitism in vertebrate hosts *Trypanosoma* and *Leishmania* stages had been obliged to change their invasion strategy and thus use blood-sucking insects as vectors to become

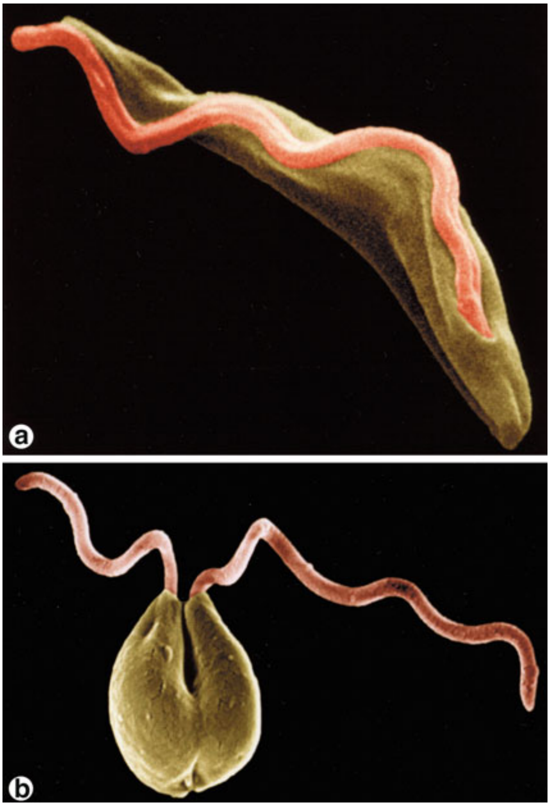


**Fig. 3.2** (**a**, **b**) SEM micrographs of blood stage of *Trypanosoma brucei gambiense* (**a**) and a dividing stage of *Leishmania tropica* from the foregut of a sand fly

transmitted from one vertebrate host to another. This makes it necessary to again live in disguise in order not to become attacked by the insect's "defence system". Thus, they have to change their surface coat again, when they arrive in the insect's intestine. In addition they must adapt their physiology inside the vector. This is seen also in the shape of the cell, since *Trypanosoma* occurs as epimastigote stages in the intestine of the insect, but *Leishmania* as promastigotes (Fig. 3.2b).

**Records of *Trypanosoma* and *Leishmania***

1. ***Living sites***: Inside blood and tissues of vertebrates, inside the intestine and salivary glands of insects
2. ***Stages***: Flagellated trophozoites, no cysts
3. ***Size***: *Trypanosoma* (8–40 μm), *Leishmania* (2–3 μm)
4. ***Characteristics***: One single flagellum, existence of a kinetoplast (= DNA-containing portion of the mitochondrion) at the basal body of the flagellum
5. ***Reproduction***: Permanent longitudinal fission
6. ***Hosts***: Vertebrates: humans, animals; insects: African trypanosomes: Tse-tse fly = *Glossina*, *Leishmania*: sand flies *Phlebotomus*
7. ***Transmission***: Transmission by blood-sucking vectors
8. ***Prophylaxis***: Use of repellents
9. ***Therapy***: *Sleeping sickness*: Suramin; *Leishmaniasis*: Diamidines

## 3.4 Cysts of Protozoans: An Invincible Castle

***My home is my castle***
***(British feeling)***

Protozoans that invade cells, tissues or organs are attacked by strong and numerous systems of host defence. In order to survive such constantly increasing attacks the parasites have to seek shelter in places, where they cannot be detected, or they have to produce walls, behind which they are protected from any attack. Thus, several protozoans developed successfully the following systems:

### *3.4.1 Parasitophorous Vacuole*

During invasion of host cells coccidians (e.g. malaria parasites, *Toxoplasma*) push the cell membrane of the host cell forward thus forming a (finally closed) inner vacuole, within which their feeding and propagation is protected from recognition by the immune system via two membranes and by the cytoplasm of the host cell (Fig. 3.3a, b). This type of cell invasion needs a very skilful system of functional organelles, which produce substances that allow penetration and feeding (e.g. conoid, rhoptries, micronemes, dense bodies, apicoplast, micropores etc.).

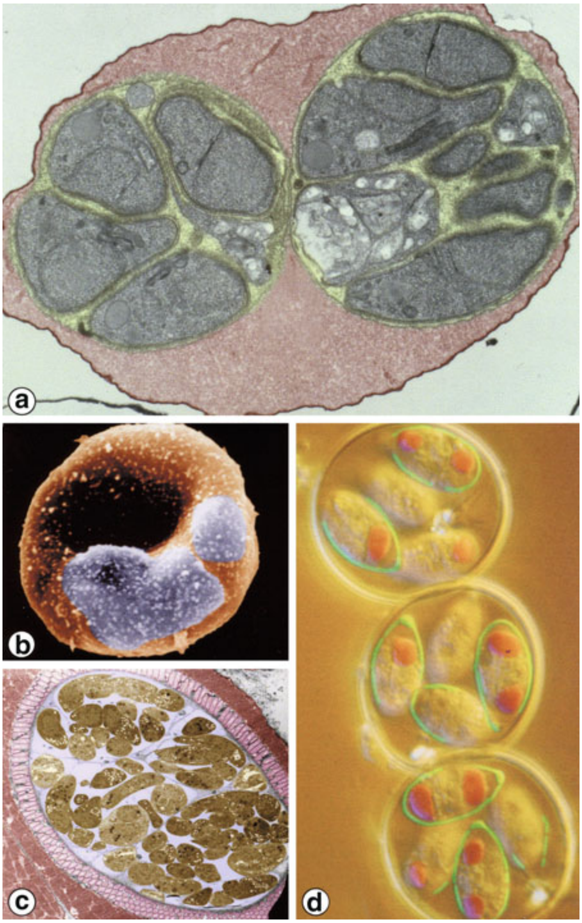


**Fig. 3.3** (**a**–**d**) Micrographs of coccidians. (**a**, **c**) Transmission electron micrographs; (**b**) scanning electron micrograph; (**d**) light micrograph). (**a**) Two schizonts of *Plasmodium falciparum* (agent of malaria tropica) lying inside their parasitophorous vacuoles are included within a red blood cell. (**b**) Two schizonts of *P. falciparum* become visible through the surface of an infected red blood cell showing the typical knobs (= *white dots*). (**c**) Section through a *Sarcocystis* tissue cyst inside a muscle fibre showing the palisade-like protrusions of the primary cyst wall and containing numerous infectious cyst merozoites. (**d**) Three oocysts of *Eimeria tenella* (agent of the diarrhoeic disease = coccidiosis of chicken). They contain four sporocysts each with two sporozoites

### *3.4.2 Intracellular Cyst (= Tissue Cyst)*

Increased protection is reached, when so-called tissue cysts are formed inside host cells (e.g. in muscles, brain cells) by some coccidians (e.g. genera *Toxoplasma*, *Sarcocystis*, *Besnoitia*). In these cases the membrane of an original parasitophorous vacuole becomes underlaid by dense material thus forming the so-called primary cyst wall (PCW), in addition this PCW may form a wall of upright protrusions, which block attacks from the outside, but also enable an increased uptake of food from the cytoplasm of the host cell (Fig. 3.3c).

### *3.4.3 Oocyst and Sporocyst Walls*

The pinnacle of protection, however, is achieved by those coccidians (e.g. genera *Eimeria*, *Isospora*, *Toxoplasma*, *Sarcocystis*) that form besides intracellular stages also extracellular ones with strong walls. The oocysts contain (like a Russian doll) other fortified systems such as wall-surrounded sporocysts, which offer excellent protection outside of a host and thus guarantee survival even during heat, dryness or coldness. Thus, these stages may survive for a long time outside of a host's body. While bacteria might harm the walls, these oocysts and sporocysts (Fig. 3.3d) are stored in laboratories inside fluids containing potassium bichromate or 1–4% of different acids, which would considerably harm human skin in case of contact.

Thus, these parasites have developed strong "castles" inside and outside of their hosts and thus remain protected in their "*home sweet home*".

**Records of Self-protectors**
1. ***Living sites***: In cells or inside cyst walls
2. ***Stages***: Merozoites, brady-, tachyzoites, sporozoites
3. ***Size***: 6–16 μm, depending on the species
4. ***Characteristics***: Penetration organelles, wall-forming bodies
5. ***Reproduction***: Endodyogeny, schizo-, sporogony, gamogony
6. ***Hosts***: All living species including humans
7. ***Transmission***: Oral uptake of cysts inside faeces or meat; other species use a vector-based transmission during blood sucking
8. ***Prophylaxis***: Avoid contact with faeces
9. ***Treatment***: Species-specific application of sulfonamides

## 3.5 Couples: Lifelong Undivorced

***True love keeps forever***
***(Hope)***

Trematodes of the genus *Schistosoma* (*Greek*: divided body) belong to the most common parasites in the subtropics and tropics attacking humans and many animals. About 500 million humans are infected and many of them are in danger of death from liver destruction and cancer, if they are not treated at an early stage of the infection. These 1–2. 5-cm long worms, which live in the blood vessels of the liver, intestine or bladder, were originally detected by a jobless German physician (Theodor Bilharz; 1825–1862), who left Germany in the 1850s and worked in Cairo, Egypt. He described in letters to his teacher von Siebold that he had found pairs of worms in livers of dead cancer patients. At first these worms were named *Distoma* referring to the two holdfast systems – a mouth sucker and a ventral sucker, which are situated close together at the anterior ends of both the female and male worm. Later the genus was named *Bilharzia*, honouring the discoverer, who is buried in Cairo. Although this genus name is the correct one with respect to the rules of Zoological nomenclature, the English literature changed the genus name to *Schistosoma*, so that today this name is retained. Humans are most commonly infected by the species *S. mansoni*, *S. intercalatum* and *S. japonicum*, which set their eggs free via human faeces, while the eggs of *S. haematobium* are excreted with the urine.

To survive inside their hosts these worms had to overcome many severe obstacles. First of all they must enter the skin of a host. This problem was solved by the development of very powerful proteolytic enzymes inside glands of the actively swimming and skin-penetrating larval stage – the bifurcated cercariae. Having successfully entered, the now tailless "schistosomulum" is immediately attacked by the host's immune system. To block these attacks this larva develops at high speed a surface coat. However, only the quickest larvae succeed and survive, while about 50% of the slower invaders are killed by the immune system leading to "not very nice reactions" in the skin of the hosts (e.g. strong inflammation and nasty itching). Then the tiny survivors (males or females) have to find a partner inside the giant tube system of the host's blood vessels. This is solved, when young worms enter the blood vessels and travel via lung and heart to the "Vena hepatica" that collects all blood arriving from the blood vessels of the intestine. The 1–2-mm-sized males and females "marry" – that is the leaf-like shaped male forms a groove, into which the young female enters and remains not only until maturity but for its whole life, which may last for 25 years or even more (Fig. 3.4a). In order to withstand the constant flow and pressure of the blood, the males of some species develop spines along their surface (Fig. 3.4b, c), which allow them to holdfast on the wall of the blood vessels, and they build up an enormous system of circular and longitudinal muscles below the syncytial tegument (neodermis), which covers as a single layer the whole body. Finally these "loving couples" have to protect themselves from the immune system of the host. This is done by wearing "foreign clothes", where male and female worms incorporate elements of the host serum into their shield. Their surface coat is demonstrated in Fig. 3.4c. Its composition is changed constantly in reply to the attacks of the rising immune system. Thus, this couple is perfectly equipped for its fight for survival having developed admirable capacities of penetration, shelter and reproduction that allow it to survive inside a hostile environment.

**Records of Schistosomes**

1. ***Living sites***: Adult worms: blood vessels
2. ***Stages***: Male and female adult worms
3. ***Size***: 1–2.5 cm
4. ***Characteristics***: Mouth and ventral sucker, non-cellular tegument, skin penetrating larvae (cercariae)
5. ***Reproduction***: *Adults*: egg-laying after fertilization, *Larvae*: division inside sporocysts in snails (intermediate hosts)
6. ***Hosts***: *Adults*: warm-blooded animals, *Larvae*: snails in water
7. ***Transmission***: Cercariae enter swimming mammals by skin penetration
8. ***Prophylaxis***: Avoid contact with water (lakes, river) in the tropics or subtropics
9. ***Treatment***: Praziquantel


**Fig. 3.4** Scanning (**a**, **b**) and transmission electron micrographs (**c**) of *Schistosoma mansoni*. (**a**) Couple; (**b**) Bosses at the surface of the male worm containing numerous hooks. (**c**) Section through the tegument of a male with spines along the surface, which is provided with deep invaginations (for additional uptake of nutrients) and the electron dense surface coat

## 3.6 Flat but Giant or Tiny: Tapeworms – The Intestine Inside an Intestine

***Appétit vient en mangeant***
***The appetite comes while eating***
***(Rabelais)***

Cestodes (*Greek*: cestos = belt, band) may reach up to 30 m in length (i.e. *Diphyllobothrium latum*, fish tapeworm of humans) and thus belong to the largest animals on earth. On the other hand the group of tapeworms also includes tiny, but very dangerous individuals of only 1–3 mm in length (i.e. *Echinococcus multilocularis* – the small tapeworm living in the intestines of foxes and dogs, which may produce eventually deadly cysts of more than 20 cm in diameter in the liver of humans). Thus, the size of tapeworms does not correspond to their pathogenous effects. Although some other human tapeworms also reach a giant size (*Taenia solium*:

4–6 m; *T*. *saginata*: 6–8 m), only a few people have seen them in full length. They live as adults in the darkness of their host's intestine, folded-back on themselves several times, so that even posterior portions of the worms come into contact with those at anterior regions. This is important, since the anterior proglottids contain the active testes of the hermaphroditic (dioecius) worms and their sperm are able to fertilize the eggs, which are produced in the female systems of the proglottids at the posterior end of the worms. The most terminal proglottids are finally pinched off from the worm's body (strobila) thus setting free the eggs, which contain the infectious oncosphaera larva. In order not to become expelled together with the host's faeces due to the constant contractions of the intestine, these worms have developed powerful holdfast systems at their head = scolex such as suckers and (often in addition) crowns of stable hooks, which guarantee a strong attachment at the intestinal wall of their hosts (Fig. 3.5a). Their giant size, however, is reached by members of the genus *Taenia* only by performing a "fratricide", which was

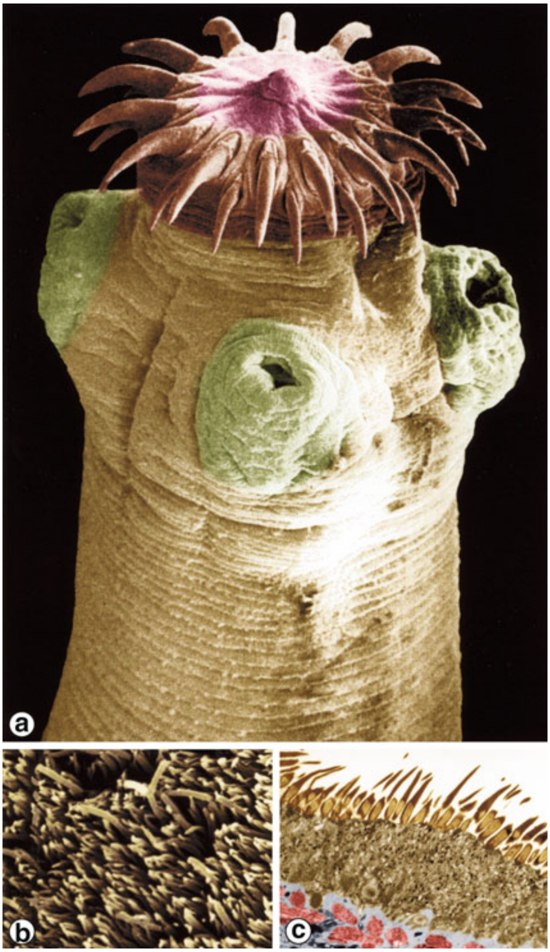


**Fig. 3.5** (**a**–**c**): (**a**, **b**) Scanning electron micrographs of the scolex (**a**) with four suckers and a crown of hooks of a *Taenia* worm and of the outer surface (**b**) with the closely arranged microtriches. (**c**) Transmission electron micrograph of longitudinal sections through the microtriches protruding from the non-cellular tegument (neodermis)

developed during evolution apparently without remaining genetic damage. This "dark side" of the life of tapeworms was discovered in the eighteenth century by the parasitologist Gottlob (= Praise God) Heinrich (Henry) Küchenmeister (1821–1890) (master of the kitchen). This human physician asked people that had been condemned to death to allow their infection by several cysticerci (= infectious stages of tapeworms) in order to check later during autopsy, how many of these larvae had grown up to an adult and healthy worm. In nearly all cases only one adult tapeworm was found in the intestine of the hosts, who had received almost luxury food during the last weeks of their life as recognition of their participation in this painless "human experiment". But even today it is not clear, how these large tapeworms manage to live alone in the host's intestine, while from some other genera several up to many cestodes may have their seat there.

Since tapeworms already live inside an intestine with enormous digestive functions, they reduced their own inner intestine, but evolved a morphologically nearly identical system along their outer surface. The non-cellular tegument (= neodermis) developed protrusions (microtriches), which look very similar to the tiny, long microvilli of the human or animal intestine and which increase enormously the surface for resorption of the host's intestinal fluid components (Fig. 3.5b, c). However, both the microvilli and the microtriches are endangered by digestion or destruction due to the activity of the intestinal enzymes. Thus, both – worm and host – have developed practically the same system of protection: they created a system of mucopolysaccharides (a so-called surface coat), which protects their surface from destruction. If these surface coats on the host cells and on the worms are not permanently present (e.g. due to intestinal diseases of the hosts or due to drug-derived death of the worms), significant damage occurs along the surface of both. Thus, a dead *Taenia solium* would be quickly digested setting free the infectious oncosphaera larvae, which may induce life-threatening brain cysticercosis (neurocysticercosis) in humans.

Since tapeworms never know, whether their faecally excreted eggs will come into contact with an intermediate host (e.g. depending on the worm species: cattle, pig) they "decided" during evolution to establish a mass production of infectious eggs. Therefore, each of the faecally excreted proglottids (= terminal portion) contains several thousand eggs, which are in addition protected by a very thick wall, which allows survival even at very low temperatures (−40 to −50°C) or even against considerable heat. While *Taenia* species have survived due to this mass production of eggs – one egg will hopefully reach its goal –, the tiny *Echinococcus* worms developed another mass strategy. In these cases thousands of the tiny worms live simultaneously in the intestine of foxes or dogs (without harming them) producing only a few hundred eggs per proglottid. However, since hundreds of worms may be present within one intestine, again hundreds of thousands of eggs are produced in order to find an intermediate host. Thus, a persisting survival of these tapeworms until eternity could be possible, were it not for the "skilful dwarfs" of the species *Homo sapiens*, who at first used plant extracts as anthelmintics (such as extracts of seeds or squeezed worm ferns) and now have developed chemical compounds such as praziquantel, which paralyze the worms and thus prevent them from attaching any longer to the intestinal wall. Thus, worm survival is not easy in our days.

**Records of Giant Tapeworms**

1. *Living sites*: *Adults*: intestine of man and animals, *larvae*: muscles of animals
2. *Stages*: *Adults* and *larvae*
3. *Size*: Giants: 1–30 m, depending on the species, dwarfs: 1–3 mm
4. *Characteristics*: Hermaphrodites, intestineless, strong holdfast systems, protective surface coat
5. *Reproduction*: Mass egg production in female system
6. *Hosts*: Giant *adults* in humans, *larvae* in pigs, cattle or fish depending on the species
7. *Transmission*: Oral uptake of cysticerci in meat of cattle/pigs or plerocercoids in fish
8. *Prophylaxis*: Avoid eating raw meat/fish
9. *Therapy of hosts*: Praziquantel

## 3.7 Tooth by Tooth – Hookworm: The Intestinal Dracula

***In sucum et sanguineum***
***(Cicero)***

Although the hookworms of the genera *Ancylostoma* (*Greek:* bended mouth) or *Necator* (*Latin*: killer) reach only a length of around 1 cm, their "blood thirst" is enormous. With the help of cutting teeth (*Ancylostoma*, Fig. 3.6) or cutting plates (*Necator*) they attach themselves to the intestinal wall of their hosts, destroy blood vessels and engorge the flowing blood with the help of their muscular oesophagus. They waste blood and just let it run through their intestine (apparently they use the included oxygen). Thus, about 100 worms deprive the host of more than 5 mL blood per day. Since often loads of more than 500 worms occur inside the 1.2 billion human hosts, anaemia and/or death (especially in children) can occur, if treatment is not carried out consistently.

Female hookworms may live for 1–2 years and thus produce millions of eggs hoping that one of the developing larvae will find an appropriate host. Again the tactics of mass production are successful in order to overcome the hostile surroundings. The females produce up to 30,000 eggs per day. Larva 1 hatches from the eggs, lives on the soil, develops into Larva 2, which after another moulting becomes the sheathed Larva 3. This infectious stage creeps together with others at the tips of blades of grass there forming a "waving tree of larvae". This peculiar behaviour guarantees that in case of contact with a host that many larvae may enter the skin at the same time. This increases the chance that female and male larvae enter the host and may become couples in the intestine. The intestine, however, is only reached after a dangerous journey via blood vessels to the heart–lung–trachea and after being engorged into the throat to reach finally the intestine, where the stages become

**Fig. 3.6** Scanning electron micrograph showing the mouth of an adult dog hookworm (*Ancylostoma caninum*). If the larva enters human skin it does not succeed in reaching the intestine, but it wanders as a "*creeping eruption*" inside the skin

mature. The males firmly clutch with their terminal "bursa copulatrix" the laterally situated sexual opening of the females. While in permanent copulation both males and females constantly suck blood and produce sperms and/or eggs. The appearance of the mouth of hookworms and their blood sucking activity reminds one of the "romantic Count Dracula", who by means of his bite offered unlimited life to his female victims (of course without permanent copulation).

**Records of Hookworms**

1. ***Living sites***: *Adults*: inside the intestine of man and animals; *larvae*: on soil
2. ***Stages***: Three free-living larvae, wandering larvae 3 and 4, adults (♀, ♂)
3. ***Size***: *Adults*: 1 cm; *larvae 3*: ~1 mm
4. ***Characteristics***: Larvae 3 penetrate into the skin and wander via blood vessels, heart, lung, trachea and finally via the oesophagus into the intestine; adults have cutting teeth or plates in their mouth, suck blood. Males hold females tightly by a posterior grip system = bursa copulatrix
5. ***Reproduction***: Sexually, females produce 10,000–30,000 eggs per day
6. ***Hosts***: Humans, animals
7. ***Transmission***: Larvae 3 penetrate into the skin, eggs are excreted via host faeces

*(continued)*

8. ***Prophylaxis***: Avoid contact to faeces-contaminated soil or grass, use shoes
9. ***Therapy of hosts***: Bendazoles, avermectines

## 3.8 Ixodid Ticks: World Record Holders in Starvation and Blood Engorging

***Feed as much as you can, you never know, when you can do it again!***
***(unknown mother tick)***

With respect to ticks there are a lot of nice but wrong fairy tales that are often repeated by different media and thus are held as true by the public. It is told that ticks drop from trees and that hats offer good protection. However, it is a fact that ticks mostly lurk for hosts (Fig. 3.7a) while sitting at the tips of blades of grass or on low plants. Furthermore, it is often told that protection can be given by making sure that the trouser leg opening is closed by a rubber band. However, it is a fact that unengorged ticks are so flat, that it is nearly impossible to squeeze them. Therefore, they easily wander below these bands onto the naked skin of the legs and seek a nice place for a blood meal. Because of this misinformation other true top records of the ticks often remain neglected, although only these skills made it possible for these rather slow animals, which are unable to fly and thus unable to leave unpleasant = hostless biotopes, to successfully survive for the last 300 million years.

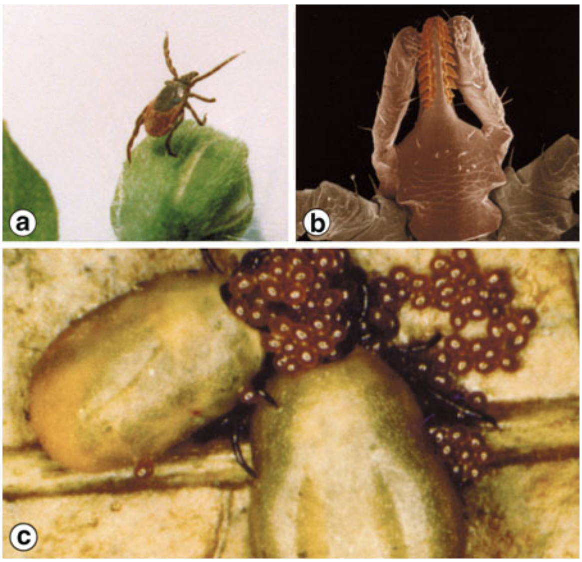


**Fig. 3.7** (**a**–**c**) Light (**a**, **c**) and SEM (**b**) micrographs of stages of *Ixodes ricinus*. (**a**) Lurking female on a plant, (**b**) anterior of the tick showing the sucking channel with hooks, which keep the tick fixed inside the skin. (**c**) Two females laying eggs on leafs

Furthermore, their ability to starve and on the other hand the amounts of blood that they can take up within 10 days are unbroken records in the whole animal kingdom. Notably the ticks of the common genus *Ixodes* (*Greek*: ixodes = glueing) are able to suck blood from huge numbers of hosts (at least more than 250 species are attacked belonging to the groups of reptiles, birds and mammals). Thus, they may use practically any type of blood as a source of their food. Bloodsucking is done by any stage of the tick's life cycle, which comprises one six-legged larva, one eight-legged nymph and both of the adults. All of these three stages suck only once in their life. This is done by injecting the anterior sucking tube (with the hooked hypostome) into the hosts' skin (Fig. 3.7b). This is followed by the activity of the knife-like cheliceres, which produce a little "blood lake" inside the skin. This "pool of blood" is kept fluid due to the anticoagulant components of the saliva, which are constantly pumped for 5–10 days into this pool. Female ticks are able to feed up to 250-times more than their body weight. This would mean that a man would have to take up at least one ton of food within 10 days. The body of the female swells from 3 to 4 mm in length reaching finally 12–15 mm. Man would have to grow to a height of 5 m. Having taken up this giant amount of blood, fertilized females are able to produce up to 4,000 eggs of a considerable size within a very short period of about 4 weeks (Fig. 3.7c).

On the other hand these ticks are also masters of starvation. Larvae, nymphs and unfed males may starve for many months (record holders survived for 10 years in the laboratory without food). Especially nymphs or females may live extremely long with the blood that they had taken up before moulting (e.g. as larvae or as nymphs). This ability was developed during evolution, since these eyeless ticks have to wait until a new host passes by close enough so that they may attach to it with the help of the tiny claws on their feet. Other ticks with eyes, however, are able to walk into the direction of potential hosts. Although their eyes are not of high quality, they can recognize the movements of possible hosts and thus run in this direction. This for example is done by the members of the genera *Dermacentor*,

**Records of Ticks**

1. ***Living sites***: Sitting on hosts, moulting on soil
2. ***Stages***: Larva, nymph, ♀, ♂ adults
3. ***Size***: Unengorged: 3–5 mm, engorged: up to 1.5 cm
4. ***Characteristics***: Blood suckers with six legs as larva, eight legs as nymph and adults; mouthparts: cheliceres, pedipalps
5. ***Reproduction***: Sexually, ♀ lay fertilized eggs
6. ***Hosts***: Many species of reptiles, birds, mammals
7. ***Transmission***: All stages lurk on plants for new hosts
8. ***Prophylaxis***: Use of repellents
9. ***Therapy/treatment***: Acarizides are placed onto the hair of animals; pinching off ticks from skin with pincers.

*Hyalomma* or *Ambylomma*. Therefore, these ticks do not need as long starvation periods as those of the genus *Ixodes*, but in any case many months may be necessary to find a new host after moulting from one stage into another. In summary the survival of ticks on earth is based on their ability to starve for long periods, to feed on giant masses of blood in short periods and to produce giant amounts of eggs in the hope that some of them may become mature ticks and may reproduce successfully.

## 3.9 Fleas: The Record Jumpers

***Jump as far as you can***
***(Unknown flea father)***

Always when highly trained human athletes jump over 2.3 m or reach even 6 m with the help of a pole, the whole stadium shouts in pleasure. However, this is nothing compared to the performance of the tiny, only 2–3-mm long adult fleas, which are able to jump from 10–25 cm in height or length – a record flea jumper was told to have reached 60 cm (perhaps supported by a gust of wind). In order to attain a comparable record a man must jump 200 m in length and at least 60 m in height. Fleas developed this ability during evolution in order to find hosts like mice, birds etc., which of course are highly motile and change their place of feeding so often that "slowly walking fleas" would have only poor chances to attack them for a nice drink of blood. Therefore, fleas have developed very long and strong hind legs (Fig. 3.8a–c), which enable them to jump over considerable distances. Having found a suitable host – fleas are not very picky – male and female fleas suck blood at least once per day for (if undisturbed) 20–150 min. However, they are easily disturbed. Then meals take only minutes. During one meal they take up 0.5 mg blood, which corresponds to a multiple of their body weight. However, this huge amount is not used for the adults alone, but serves also for the larvae (Fig. 3.8d), since portions of the blood are released via the anus (about 20–40 times per hour). Thus adults "drink for their kids = larvae", which live on the soil, in human beds, in the nests of birds or on the sleeping place of pets. This type of blood meal, which benefits the survival of the progeny, may be repeated several times per day. On the other hand fleas are also masters in the discipline of "starvation", since adult fleas can wait inside the pupal cocoon for months (e.g. in bird nests) until a trembling announces the arrival of new hosts. Also unfertilized females may starve for long periods and – if getting blood – they may live for up to 5 years. Fertilized females, however, become exhausted after 3 months due to their production of about 450 of the 0.5-mm long, white, ovoid eggs.

Of course flea bites (that are often found in rows) are not nice due to their itching effects. However, fleas are really dangerous due to a particular non-polite behaviour during the blood-sucking act. If fleas are disturbed during blood sucking, they may change host and start another blood meal on the new host. However, since they suck hastily, their foregut becomes overfilled, and some portions of the blood masses

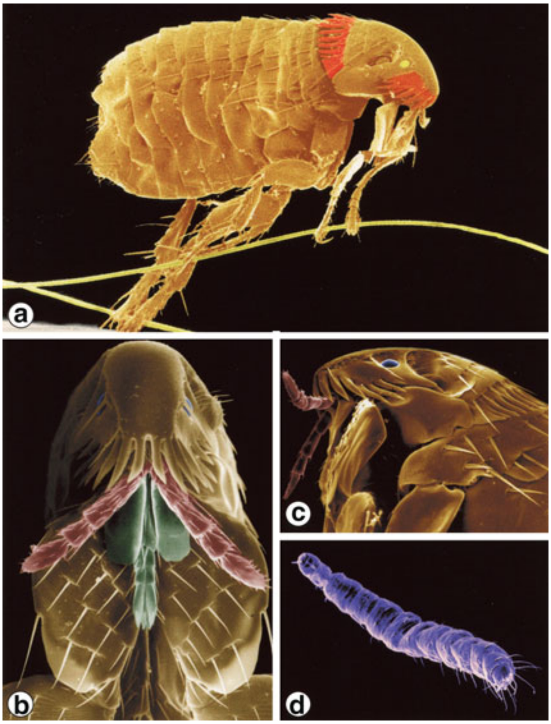

**Fig. 3.8** (**a–d**) Scanning electron micrographs of the developing stages of the cat flea *Ctenocephalides felis*, which represents about 80% of the flea population on human cats and dogs

may become regurgitated into the wound. This blood may contain portions of the blood of the preceding host. In case this host contained agents of diseases such as plague bacilli or several viruses (as was shown 2007–2009 by the groups of Mencke and Mehlhorn) the second host may become infected, too. As a consequence fleas are serious vectors and represent a big epidemiological problem, especially in locations crowded by man. Therefore, treatment of animals with insecticides and flea eradication in hospitals, camps or in human family dwellings is very important.

**Records of Fleas**

1. ***Living site***: Adult and larvae: bed of man, rest places and nests of animals
2. ***Stages***: Larvae (three stages), pupa, ♂, ♀
3. ***Size***: *Adults*: 1–6 mm (depending on the species)
4. ***Characteristics***: Adults: wingless, six legs, last pair of legs are long and strong, blood suckers; *larvae*: without legs, many surface bristles
5. ***Reproduction***: Sexual, holometabolic life cycle including a pupa
6. ***Hosts***: Mainly birds and mammals
7. ***Transmission***: Jumping activity of ♂, ♀
8. ***Prophylaxis***: Repellents
9. ***Therapy***: Insecticides against *adults*, inhibitors of moult against *larvae*

## 3.10 Bed Bugs: The Stinking High-Speed Runners in the Dark

***Running until blood comes***
***(Wisdom of recruits)***

Bed bugs – about 6–8 mm in length (*Cimex lectularius*: *Latin*: lectulus = little bed) have been companions of humans since the days humans ceased their nomadic life and became sessile in common places and built homes for shelter. Apparently birds and rodents imported the blood suckers from their nests into human dwellings, where they became active during the night. Then this armada of heavy blood suckers (larvae and adults) leaves their protected places in beds, behind desks or wall coverings and runs towards their sleeping hosts. During one sucking act that takes about 15 min, each bed bug may take up about 7 mg of blood until its body is completely stretched. Unfed bugs even attack their "brothers" and suck blood from their abdominal bodies. The blood loss from hosts due to the attacks of numerous bed bugs may be considerable. For example, about 180 adult bed bugs may kill a mouse due to the enormous loss of blood. Initially the bed bug's bites are not painful and hosts do not notice them. However, after some hours itching at the biting site draws the attention of the host to the previous sucking act. When attacking hosts, bed bugs may run very quickly covering 1.25 m within 1 min. This distance represents the 200-fold of their length. Thus, a man of 1.8 m in length must run at least 360 m within 1 min in order to show the same performance. This can be done by highly trained male humans, who afterwards are completely exhausted, while bed bugs run further distances whilst maintaining the same speed. Bed bugs are very social animals. Their abdominal glands excrete an odour, which stinks to humans, but which holds the society of bed bugs together in a room. This makes it easy for bed bugs to find a sexual partner, but humans suffer twice: from the follow up of the wounds and from the stink in their rooms. The blood is imperative for the reproduction of bed bugs. Fed females are very busy and lay up to 12 eggs per day (in total about 500 during their life span). Bed bugs reach within 22 days via five larval stages (without pupa) maturity and the reproduction process starts again. Therefore humans, who have bed bugs in their rooms, will never remain alone (Fig. 3.9).

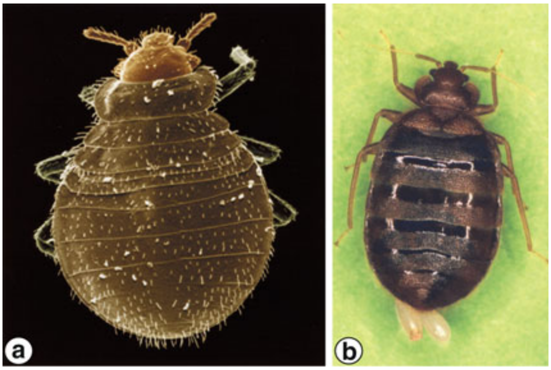


**Fig. 3.9** (**a**, **b**) Scanning (**a**) and light micrographs (**b**) of bed bugs from their dorsal side. In (**b**) the female is about to lay eggs

**Records of Bed Bugs**

1. ***Living site***: Hidden in human dwellings, beds
2. ***Stages***: Five larval (nymphal) stages and adults (♂, ♀)
3. ***Size***: Up to 8 mm
4. ***Characteristics***: Brown, wingless insects with sucking mouthparts
5. ***Reproduction***: Hemimetabolic life cycle (development without pupa)
6. ***Hosts***: Humans, birds, mice
7. ***Transmission***: Bed bugs are imported into homes with luggage or furniture
8. ***Prophylaxis***: Check luggage and furniture before transportation into a home
9. ***Therapy***: Insecticides which have to be used at least twice

## 3.11 Head, Pubic and Body Lice: The Heavy Clingers

***Hairless heads are too slippery for lice***
***(Fact)***

The blood-sucking lice of humans (Fig. 3.10a–d):

- *Pediculus humanus capitis* (head louse: *Latin:* pediculus: little foot)
- *Pediculus humanus corporis* (body louse)
- *Phthirus pubis* (pubic louse, *Greek*: phtheir: louse)

are excellent clingers. These wingless insects have developed a giant claw at each of their six legs, so that any of these claws is able to clutch a separate hair. This means that it is difficult to separate lice from their host. This is very important because these three lice species have lived for about 15 million years exclusively on the body of humans and their precursors. The first human lice apparently lived exclusively inside the hair, while later – when humans created clothes for cold periods – the body lice separated from the main development. Body lice often glue their eggs onto the inside of human clothes, while head lice exclusively attach the eggs to the hair (Fig. 3.10d), as is done by the pig species *Haematopinus suis* (Fig. 3.10c). Head lice only detach willingly from their hosts in case of two events:

1. The host dies and its surface temperature decreases. The same often happens during surgery, when the skin temperature decreases considerably. This is noted by the lice and viewed as a stimulus to look for another host.
2. Fertilized females of head lice run just after their blood meal towards the end of hair and lurk there for another host. If there is a hair-to-hair contact, the females change host and become the grand-grandmothers of a new population. If there is no hair-to-hair contact within the hour following sucking, they return to the head’s surface, suck again and glue some eggs at the base of the hair of their present host.

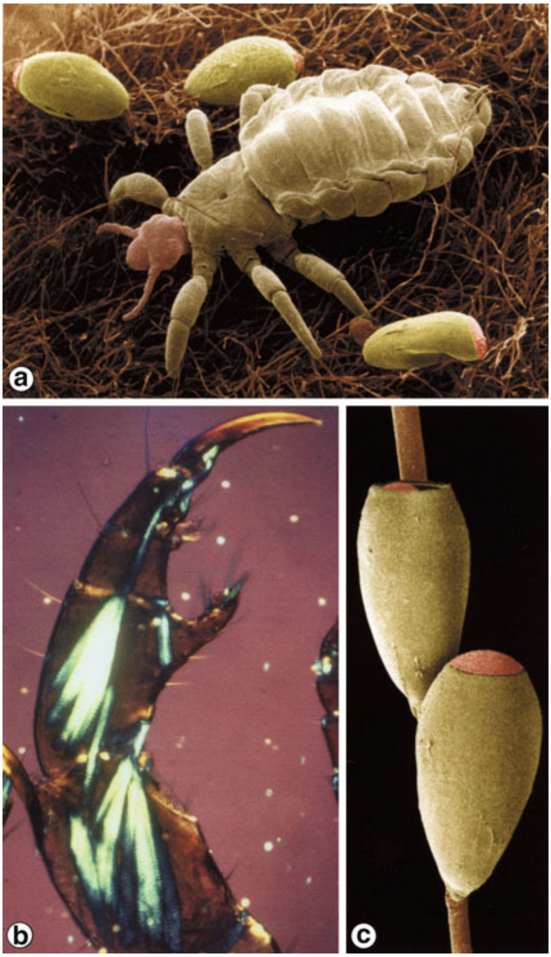

**Fig. 3.10** (**a**–**e**) Scanning (**a**, **c**, **d**, **e**) and light micrographs (**b**) of lice. (**a**) Body louse with eggs glued to human clothes. (**b**) Nomarski-aspect of the strong muscles inside the legs of lice enabling them as clingers in the “hair forest”. (**c**) Pig louse: *Haematopinus suis*: one egg with operculum, the second without – both being glued on a hair. (**d**) Egg of a human head louse showing the typical operculum with aeropyls. (**e**) Crab or pubic louse

Thus, head and pubic lice only change their hosts during body contacts. Therefore, the French named the pubic louse also “papillon of love” = butterfly of love. Richness in lice was not always considered a sign of bad hygiene, as in the sixteenth to eighteenth century it was believed that possession of many lice was an indication of high sexual potency in males, since it was believed that lice suck away “bad body fluids”, while the “good” ones remain. All stages of the life cycle of lice suck blood: all three larval stages and both females and males. Females suck up to 1.1 mg per meal, which is ingested every 2–3 h. Males need less blood, since they do not lay 5–10 eggs per day as is done by the females. Males suck about 0.3 mg blood per meal. Starvation is bad for head lice. At 37°C they survive only for 24 h at the maximum without blood, while body lice may survive for up to 10 days – especially if temperatures are low (12–20°C). Thus, in the case of head lice there is no need to clean the bed or clothes of lice which occasionally drop down from a crowded head.

In some records more than 20,000 head lice had been counted on a single person – a real festival. The eggs – covered by an operculum (Fig. 3.10d) with aeropyles (for the entry of oxygen) – are miracles of stability. They become glued at the base of hair with the help of a water-insoluble substance and are protected by a chitinous shell (nit). Thus, even combs with very closely standing teeth are not useful to detach most of the eggs reaching a length of 0.8 mm and diameters of 0.2 mm. While head and pubic lice are surely nasty visitors of humans, body lice may become dangerous, since they may transmit agents of diseases such as *Rickettsia prowazekii*, which may introduce outbreaks of a disease of the spotted fever group (a possibly deadly disease in untreated cases).

Thus, the development of the strong claws has enabled the three human lice species to live truly for some millions of years with humans and their precursors.

**Records of Lice**

1. ***Living site***: Human body (exclusively)
2. ***Stages***: Three larvae, ♂, ♀
3. ***Size***: *Head louse*: 3 mm, *body louse*: 4 mm, *pubic louse:* 1.5 mm
4. ***Characteristics***: Strong claws, eggs become glued to hair or clothes
5. ***Reproduction***: Sexual intercourse
6. ***Hosts***: Exclusively humans
7. ***Transmission***: Hair-to-hair contact (*head louse*), contacts of clothes and/or bodies (*body* and *pubic lice*)
8. ***Prophylaxis***: Avoid hair-to-hair contact respectively body contacts with unknown people
9. ***Therapy***: Use of good and efficacious hair and body shampoo (such as Wash Away Louse or Lincin)

## 3.12 Antarctic Lice: The Inventors of the Diving Suit

***Oh, how cold is your little hand***
***(La Boheme)***

All those that believe lice like it warm will be sceptical on talk of the lice of seals belonging for example to the genus *Antarctophilus* (Fig. 3.11a–d). The Weddell seals and related species live and hunt in the very cold (−1.7°C) waters of Antarctica, so that their fur should be icy from the skin until its very end. However, lice of different blood-sucking species are often found closely attached to the skin while sucking blood. Considering that the fur of the seals is often exposed to temperatures as low as –40°C, after they have left the water and are exposed to the winds, it is nearly unbelievable that these lice survive in such an environment. This is, however, possible, since these lice have developed a multi-layered cuticular surface consisting of overlapping scales. In between these scales layers of the fat

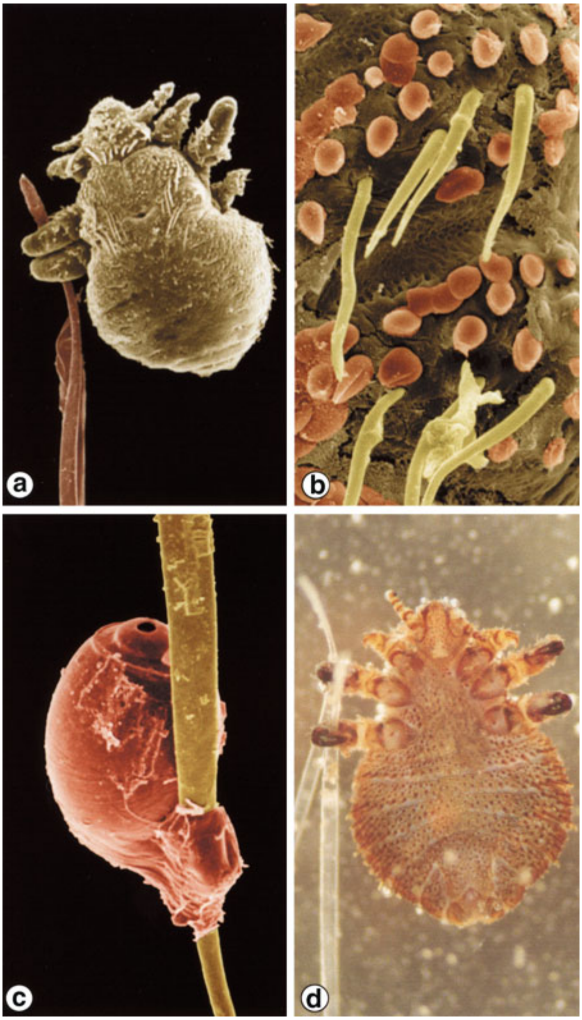


**Fig. 3.11** (**a**–**d**) Scanning (**a**–**c**) and light (**d**) micrographs. (**a**, **d**) Adult lice clinging to a seal's hair. (**b**) Knobs and hair at the dorsal surface fixing the cover made by the seal's surface fat. (**c**) Egg being glued with water-insoluble material on a hair of the seal. Note the single opening (aeropyl) of the cover (operculum)

excreted by the body surface of the seal become mingled. In addition at several places air spaces persist thus producing a multi-layered cover, which surely protects against freezing. Furthermore the whole surface of the lice is topped by another thick layer of the seal's surface fat being fixed by short, knob-like protrusions and longer hair (Fig. 3.11b). The inner body of these lice is heated by the permanent uptake of the warm blood of the seal. In addition this multi-layered surface of the lice is very helpful, when the seals begin diving (up to 600 m deep). Then this layer becomes smoothly depressed and the surface fat is squeezed out from the space between the cuticular scales, as the seal dives down, and is refilled again, when the seal again reaches the surface of the water. Besides this perfect protection of the Antarctic lice another miracle remains, however, unsolved: from where does the heat come from that starts and keeps running the "motor" of embryo development inside the nits, which are glued (as in the case of other lice) by *Antarctophilus* females onto the hair of the seals (Fig. 3.11c)?

**Records of Antarctic Lice**

1. ***Living site***: Inside the fur of diving seals
2. ***Stages***: Three larvae, ♀, ♂
3. ***Size***: Adults: 2 mm in length
4. ***Characteristics***: Surface scales creating a diver's suit; highly compressible; claws at their feet
5. ***Reproduction***: Sexual intercourse, nits are glued to the hair of the host
6. ***Hosts***: Antarctic and arctic seals
7. ***Transmission***: During body contacts of the hosts
8. ***Prophylaxis***: None in the wilderness
9. ***Therapy***: None in the wilderness, bath treatments with anti-lice shampoos in the zoo.

## 3.13 The Super Moms: Tse-tse Flies

***Oh babe, I keep you in your dreams***
***(Folk song)***

Tse-tse flies – the African relatives of our European biting flies (e.g. *Stomoxys calcitrans*: *Greek*: with pointed mouth) – are also called tongue flies (genus *Glossina* = *Latin* = tongue), since they protrude their mouthparts like a tongue and since their folded wings look like a tongue when seen from above, as the fly is at rest (Fig. 3.12a, b). Both sexes suck blood from motile hosts, being attracted by movement. The amount of blood taken up during a single blood meal varies depending on the species. For example *Glossina palpalis* sucks 30 mg of blood at short intervals. *Glossina morsitans* (*Latin*: the biting one) takes up 90 mg per meal and *G. brevipalpis* may ingest even up to 260 mg thus feeding 3–4-fold their own body weight. If man would do the same, he would have to eat up to 150 kg in one meal. Such blood meals are repeated by the *Glossina* individual at intervals of 3–6 days. During, before or after feeding they may meet their sexual partners on the host, while during the rest of the time they live as "lonely riders" far away from hosts. This behaviour leads to the fact that hosts are not really disturbed by *Glossina* specimens and their limited blood meals. Furthermore, this behaviour makes it difficult to kill them through application of insecticides, which must be sprayed at high dosages in order to reach a long-lasting protection. Another behavioural peculiarity brought an exceptional advantage in the fight for survival. While non-biting, normal flies rely on mass production of eggs – hoping that a few of them reach the adult stage – the glossines have developed a unique way of caring for their

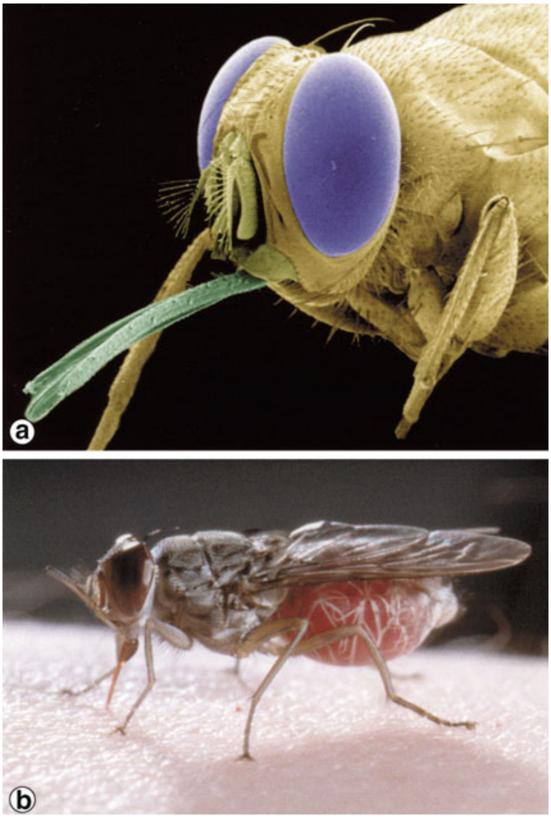

**Fig. 3.12** (**a**, **b**) (**a**) Scanning electron micrograph of the anterior end of a *Glossina* specimen. (**b**) Light micrograph of a *Glossina* female during bloodsucking on human skin

progeny. The females do not deposit eggs somewhere on the soil, on faeces or on dead bodies, but keep them inside their body within a peculiar "brood chamber". The first hatched larva suppresses the development of the others, uses their resources and in addition is fed by excretions of the wall of the brood chamber. These glands are described as "milk glands". After a developmental period of 8–14 days the larva, which is ready to pupate, is finally deponed into sand. The pupa finally gives rise to the "ready-to-bite" adult female or male. Because of this excellent "brood-care-system" the progeny of the glossines has the "best cards" in the fight for survival. Therefore, it is sufficient that each female produces only 10–20 "kids" during its 3–7 month-long life span in order to maintain a reasonable population in a given biotope. These "super moms" even contribute to the expansion of the population, since they import – like aircraft carriers – their progeny into new biotopes. This peculiar behaviour endangers humans and their stock animals considerably, since glossines are the vectors of the agents of the deadly trypanosomiasis, which even today is not treatable with a reasonable survival rate.

**Records of the *Glossina* Species**

1. ***Living site***: Free in the savannahs of Africa, preferring dark hiding places
2. ***Stages***: Larval development inside the mother; free pupae and adults living for 3–7 months
3. ***Size***: Adults: ca. 10 mm
4. ***Characteristics***: Blood-sucking mouthparts directed straight forward
5. ***Reproduction***: Sexual intercourse
6. ***Hosts***: Cattle, antelopes, humans, rodents, crocodiles, other wildlife etc.
7. ***Transmission***: Adults search their hosts
8. ***Prophylaxis***: None in the wilderness
9. ***Therapy***: None in the wilderness, insecticides in farms

## 3.14 Having Beautiful Eyes: But Not Needing Them – Mosquitoes During Attack

***Look into my eyes, babe***
***(Humphrey Bogart – in Casablanca)***

Who does like the buzzing sound of attacking mosquitoes (from *Portuguese: mosquitos* = biting insect), while waiting for the benefits of the arriving god of sleep in a quiet bedroom? Surely nobody. Of course – the bite itself does not initiate pain, since the female mosquito injects its saliva, which contains besides anticoagulants and vessel-enlarging components also anaesthetics that at first make the bite unnoticeable. However, all these elements may induce intense immune system reactions, so that – depending on the host – quick or slow local symptoms occur such as intensive itching, formation of skin papulae, local inflammations etc. Only female mosquitoes suck blood via their two-channel-mouthparts directly from blood vessels. Thus, they are named "vessel-feeders", while other biting blood suckers such as ticks, simuliids or tabanids cut little "lakes" within the skin and thus are named "pool-feeders". The nasty "attacking music" of female mosquitoes is produced by the beating of their two large forewings and their two tiny back wings (halteres) at a magnitude of around 350–450 Hz (depending on the species). This frequency is even topped by the males, where in some species even 1,000 Hz may be reached. In many species males, which feed – if at all – on plant juices, form large swarms of "dancing" individuals. These swarms appear as clouds of dark smoke close to bushes along little creeks, lakes etc. The females fly into these clouds and become fertilized even during flight. After that they try to get a blood meal from a host and start about three days later with the deposition of 50–250 eggs mostly onto the surface of water. This procedure is repeated several times (depending on the temperature, availability of hosts and species peculiarities): for example the European fever mosquito *Anopheles maculipennis* produces about 2,500 eggs which are deposed during ten different acts. Mosquitoes may occur as part of a population of millions of individuals. These enormous reproduction rates, which prohibit human settling in many regions of the earth, are only possible, since the mosquitoes have developed through the course of evolution many admirable world records in the field of physiological abilities. For example, adult mosquitoes may hibernate in temperate climates and even at very low temperatures for many months. This does not stop their fecundity in the next spring. Females of *Culex pipiens* (the piping mosquito inside houses) and those of the fever mosquito *Anopheles maculipennis* become fertilized for example in November, starve until March, then suck blood and deposit their eggs onto the surface of water. Other species hibernate as eggs (*Aedes cantans* = the singing one) or larvae (*Mansonia richardii, Aedes nemorosis*) in the mud of frozen ponds etc. The larvae of some species (e.g. *Aedes mariae*, several *Culicoides* species) have learnt to survive even inside salt water. All this needs a high level uptake of food in order to produce the needed energy: larvae filtrate large amounts of proteins from their biotope and female mosquitoes are able to suck within a few seconds up to the fivefold of their body weight (e.g. *Anopheles gambiae*: 2–5 mg; *Aedes aegypti*: 4 mg; *Culex quinquefasciatus*: 6–10 mg, *Psophora ciliata*: 25 mg), while pool-feeding midges only suck 0.001 mg. Sucking of mosquitoes is done through use of the pressure inside the blood vessels, into which they inject their two-channel-system mouthparts (one channel is used to introduce the saliva, the other to engorge the blood meal). These meals are repeated every three days enabling the females to lay eggs. However, one meal may also be sufficient to survive for a whole winter in a quiet, non-freezing location somewhere in a house or within a protected shelter in nature. Of course, many of these individuals will die – but the mass production of the progeny guarantees survival of sufficient specimens to generate the following generations of blood suckers. Mosquitoes possess large compound eyes with numerous ommatidia of the "apposition" type (i.e. being clearly separated from each other; Fig. 3.13a–d). They are of high importance for finding hosts in the case of daytime active mosquitoes such as many *Aedes* species = forest and bush mosquitoes. However, many species are active at night or during dawn and dusk and thus these species rely on further abilities. They therefore developed highly sensitive receptors for different odours, which enable them in the dark to find hosts over distances of up to 20 m. More than 40 different components have been determined to be attractive to mosquitoes, if they are mixed within the "skin perfume" of humans. This explains why some persons are more attractive than others possessing a varying coat along their skin. $CO_2$ and body warmth, however, are very important components that stimulate female mosquitoes to become nasty aggressors against peacefully sleeping persons. Since mosquitoes inject saliva into the blood vessels of their hosts in order to keep the blood meal fluid, this saliva may be contaminated with agents of diseases such as malaria parasites or many viruses that may introduce life-threatening diseases such as Yellow Fever, Dengue Fever, Rift Valley Fever etc. Happily this does not occur in temperate zones of the earth, but is not excluded in further times of intense globalization and global warming. Other blood suckers like midges (genus *Culicoides*) or black flies (genus *Simulium*) are already known as vectors of diseases in Europe. *Culicoides* species led to an outbreak of Bluetongue disease in ruminants in Europe during the years 2006–2009 and *Simulium* species (the vectors of onchocerciasis = river blindness in Africa) may transmit skin filariae or introduce painful

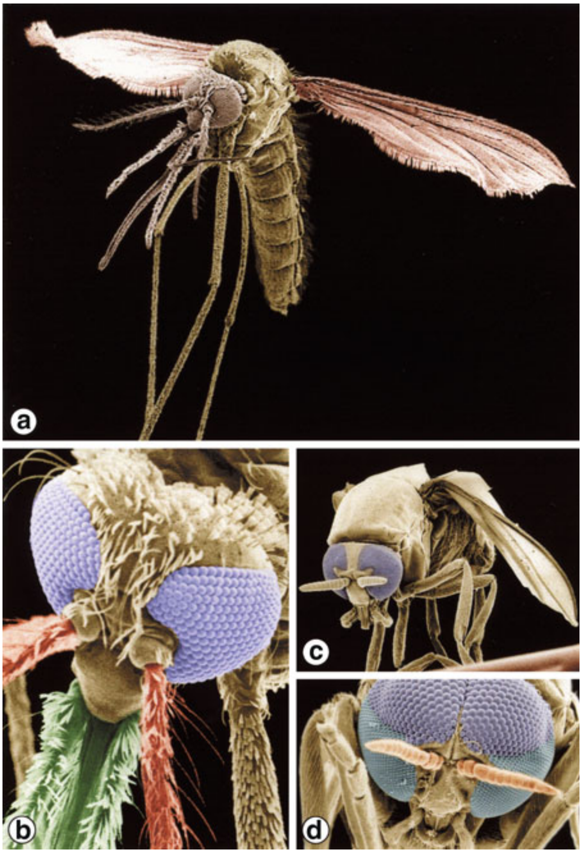

**Fig. 3.13** (**a**–**d**) Scanning electron micrographs of mosquitoes. (**a**, **b**) *Anopheles stephensi* (8 mm), (**c**) *Simulium morsitans*, female (3 mm). (**d**) Head of a male showing smaller lower ommatidia

wounds at their biting sites. Both *Culicoides* species and simuliids are "pool-feeders" cutting tiny blood lakes into the skin, which often become additionally superinfected by bacteria.

The males of the genus *Simulium* developed two types of ommatidia inside their compound eyes (Fig. 3.13d). There are smaller ommatidia at the lower side of the eye and larger ones at its upper rim. Thus, these species apparently have developed a type of "glasses for reading", that is recognition of details at narrow distances, since these smaller ommatidia should produce sharper pictures in their tiny "brains".

**Records in the World of Mosquitoes**

1. ***Living site***: Larvae, pupae: water; adults: air, blood-sucking females, worldwide
2. ***Stages***: Larvae (4–5), pupa (1), ♀, ♂
3. ***Size***: *Adults: Aedes:* (2–4 mm), *Anopheles* (5–8 mm), *Culex* (4–6 mm)

*(continued)*

4. ***Characteristics***: Females suck blood (up to 5-fold of their body weight), large eyes, vessel feeder, attracted by body odours
5. ***Reproduction***: Sexual intercourse
6. ***Hosts***: Warm-blooded hosts, reptiles, amphibia
7. ***Transmission***: Females are attracted by body odours
8. ***Prophylaxis***: Humans may become protected by nets and repellents (such as Viticks Cool®, Autan®)
9. ***Therapy***: After bites: cooling of wounds, use of antihistaminica, medicaments against transmitted agents of diseases

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