Dermatobia
(insect: dipteran)

Overview

Arthropods are coelomate metameric invertebrate animals with a chitinous exoskeleton and jointed limbs. They undergo protostomial embryonic development and grow by cuticular moulting (ecdysis). Three main subphyla are recognized: Chelicerata, Crustacea and Hexapoda. Insects are hexapods with three pairs of uniramous legs, three tagmata (head, thorax, abdomen), ectognathous mouthparts with whole-limb mandibles, and one pair of antennae. Diptera (true flies) have two pairs of wings, but the hindwings are reduced to stabilizing halteres. All species are holometabolans and exhibit complete metamorphosis whereby vermiform larval stages undergo pupation and transform into free-flying adults. Several major parasitic groups are recognized: nematocerans (small slender bodies, long filamentous antennae, narrow wings) and brachycerans (larger bodies, short stout antennae, broad wings); the latter being divided into the Tabanomorpha (larval head capsule sclerotized) and the Muscomorpha (larval head not sclerotized, circular-seamed (cyclorrhaphous) pupae). Muscomorphans include the glossinids (tsetse flies), hippoboscids (louse flies), muscids (house flies), calliphorids (blow flies), sarcophagids (flesh flies) and oestrids (bot flies); all with sponging or biting mouthparts. These flies are either ectoparasitic with adults biting hosts (former three groups) or endoparasitic with vermiform larvae developing in host tissues (latter three groups). Oestrids (bot flies) are large hairy flies but they are not parasitic as adults. Their larvae (bots) are obligatory endoparasites in the integumentary, respiratory or digestive tracts of animals, and they exhibit a high degree of host specificity. Four subfamilies are recognized: cuterebrines (skin bots), oestrines (head maggots), gasterophilines (stomach bots) and hypodermatines (cattle grubs/warbles). Cuterebrine larvae of *Dermatobia* spp. cause cutaneous myiases in many warm-blooded animals, including humans. Their life cycle is unusual in that adult flies lay eggs on carrier insects, mosquitoes and other flies, which then transfer them to vertebrate hosts.

Classification:

Domain:	Eukaryota (membrane-bound nucleus)
Supergroup:	Amorphea (unikonts with single flagellum, or nonflagellated amoebae)
Kingdom:	Metazoa (multicellular eukaryotes, heterotrophs, notably animals)
Group:	Protostomia (triploblastic, spiral cleavage)
Subgroup:	Ecdysozoa (cuticle moulted = ecdysis)
Phylum:	Arthropoda (chitinous exoskeleton, segmented body, jointed limbs, haemocoel)
Subphylum:	Hexapoda (three tagmata, three pairs uniramous legs, whole-limb mandibles, Malpighian tubules)
Class:	Insecta (ectognathous mouthparts (bases lie outside head capsule), single pair antennae, many with wings)
Superorder:	Holometabola (Endopterygota) (young do not resemble adults, pupae, with internally developing wings)
Order:	Diptera (true flies, single pair of forewings, hindwings modified into halteres, vermiform larvae)
Suborder:	Brachycera (tabanid/March flies, short stout antennae often with aristae, telmophagy)
Infraorder:	Muscomorpha (Cyclorrhapha) (flies, cyclorrhaphous (circular-seamed) pupae, larval head not sclerotized)
Division:	Schizophora (head with frontal suture (lunule))
Section:	Calyptratae (calypters cover halteres)
Family:	Oestridae (large hairy bot flies, third larval stage or bot resemble small sausages, larvae cause myiases)
Subfamily:	Cuterebrinae (skin bot flies)
Genus:	*Dermatobia* (parasitic on skin of cattle/humans)
Species:	various species cause cutaneous myiases

Parasite biodiversity and host range: Most Metazoa are multicellular triploblastic animals with differentiated tissues, many being bilaterally symmetrical with a body cavity. Most invertebrate animals are protostomes as their embryonic development involves spiral determinate cleavage. Those that moult their external cuticles during their life-cycles (process known as ecdysis) are grouped together in the unique clade Ecdysozoa, including the nematodes (roundworms), onychophorans (velvet worms), tardigrades (water bears) and arthropods (myriapods, chelicerates, crustaceans and hexapods). Arthropods have small segmented bodies encased in chitinous exoskeletons with articulated limbs. Most species are free-living in terrestrial and aquatic habitats, although a small range are ectoparasitic on other animals, some feeding on the blood or skin of vertebrates. Five subphyla are recognized: Chelicerata, Crustacea, Hexapoda, Myriapoda and Trilobita. Insects are hexapods with six legs, three distinct body parts, two antennae and mouthparts with whole-limb mandibles. Insects are the most biodiverse group on the planet, with millions of species described in numerous taxa. Notorious ectoparasitic species belong to four orders in two superorders: the Hemipterodea (Exopterygota) containing the orders Hemiptera (bugs) and Phthiraptera (lice); and the Holometabola (Endopterygota) containing the orders Siphonaptera (fleas) and Diptera ('true' flies). Flies are small winged holometabolans that undergo complete (holometabolous) metamorphosis with vermiform larvae undergoing pupation in silk cocoons. Thousands of dipteran species have been described throughout the world, most being free-living saprophages (detritivores) but some being parasitic either as adults biting and feeding on hosts (often haematophagous) or producing larvae that invade host tissues (condition known as myiasis). Two major suborders are recognized: the Nematocera (with small bodies, long filamentous antennae, narrow wings and aquatic larvae and pupae); and the Brachycera (with large bodies, short stout antennae often with aristae and broad wings).

Major parasitic dipteran families	Biodiversity	Parasitic stages	Status	Pathogenesis*	Disease transmission
Suborder: Nematocera (small midges/mosquitoes, thread-horned with long filamentous segmented antennae (= nemato-cera), aquatic life-cycles (larval/pupal stages associated with water), female adults require blood meal before they can lay eggs) (34 families)					
Culicidae (mosquitoes)	3 subfamilies, 70 genera, 3,500 species	adult ♀	obligate	blood-sucking	viral, protozoal, helminth
Psychodidae (moth flies, sand flies)	5 subfamilies, 150 genera, 3,000 species	adult ♀	obligate	blood-feeding	viral, bacterial, protozoal
Simuliidae (black flies)	3 subfamilies, 30 genera, 2,000 species	adult ♀	obligate	blood-feeding	protozoal, helminth
Ceratopogonidae (biting midges)	4 subfamilies, 110 genera, 6,000 species	adult ♀	obligate	blood-feeding	viral, protozoal, helminth
Suborder: Brachycera (large tabanid/March flies, with stout and fewer antennal segments (= brachy-cera), antennae often with aristae, females with slashing-sponging mouthparts to pierce skin and feed on pool of blood (telmophagy)) (120 families)					
Infraorder: Tabanomorpha (larval head capsule incomplete posteriorly (only anterior parts sclerotized))					
Tabanidae (horse flies, deer flies)	3-5 subfamilies, 133 genera, 4,300 species	adult ♀ [+ larvae]	obligate [accidental]	blood-feeding [GI, UG, TR myiasis]	viral, bacterial, protozoal, helminth
Infraorder: Muscomorpha (Cyclorrhapha) (aristate antennae, setose bodies, cyclorrhaphous pupa)					
Section: Calyptratae (calypters cover halteres)					
Superfamily: Muscoidea (synanthropic flies)					
Muscidae (house flies, stable flies)	9-10 subfamilies, 190 genera, 4,200 species	adult ♀, ♂ [+ larvae]	obligate [accidental]	biting, blood-feeding [CU, GI, TR myiasis]	bacterial, helminth
Superfamily: Oestroidea (cause larval myiases) (6 families)					
Calliphoridae (blow flies)	11 subfamilies, 75 genera, 1,100 species	larvae	facultative, obligate	CU, GI, NP, AU, UG TR, myiasis	-
Sarcophagidae (flesh flies)	3 subfamilies, 108 genera, 2,500 species	larvae	facultative, obligate	TR, GI, CU myiasis	-
Oestridae (bot flies, warble flies)	5 subfamilies, 25 genera, 150 species	larvae	obligate	CU, GI, NP, OC myiasis	-
Superfamily: Hippoboscoidea (pupa-bearers)					
Glossinidae (tsetse flies)	1 genus, 3 species-groups, 25 species	adult ♀, ♂	obligate	blood	protozoal
Hippoboscidae (louse flies, keds)	1-3 subfamilies, 21 genera, 212 species	adult ♀, ♂	obligate	blood	viral, protozoal, helminth

*type of myiasis: AU = auricular; CU = cutaneous; GI = gastro-intestinal; NP = naso-pharyngeal; OC = ocular; TR = traumatic; UG = uro-genital.

The suborder Brachycera contains 6 infraorders: Asilomorpha (bee flies, robber flies, spider flies), Muscomorpha (previously suborder Cyclorrhapha) (house flies, blow flies, fruit flies), Stratiomyomorpha (soldier flies), Tabanomorpha (horse, deer and snipe flies), Vermileonomorpha (wormlions) and Xylophagomorpha (awl flies); all of which vary considerably in their morphological and biological characteristics. Members of the infraorder Muscomorpha differ from the others in that they form cyclorrhaphous (circular-seamed) pupae (adults eclose through a circular cap rather than a longitudinal slit), larvae without sclerotized heads, and adults with short pendulous 3-segmented antennae (the third segment often bearing feather-like aristae), palps with a single segment, and feet with 2 pads. Collectively, 15 superfamilies have been classified into 2 Divisions: the Schizophora (containing flies whose heads bear a frontal ptilinial suture and sclerotized lunule); and the Aschiza (hover flies lacking a frontal suture and lunule). Within the Schizophora, 2 sections are recognized: the Calypterae (comprising flies with calypters covering the halteres, large squamae, a strong thoracic suture and well-defined grooves on the antennal pedicels); and the Acalypterae (without

covering calypters, small squamae, a weak thoracic suture and no pedicel grooves). Calyptratae flies are divided into 3 superfamilies: Muscoidea (synanthropic flies with well-developed sponging mouthparts for feeding on decaying organic material or biting mouthparts for blood-feeding, most females being oviparous (egg-layers)); Hippoboscoidea (louse flies and tsetse flies with elongate biting mouthparts for blood-feeding, female flies formerly regarded as pupa-bearers and placed in group Pupipara (now defunct) as they have since been shown to birth mature larvae (considered to be prepupae)); and Oestroidea (blow flies, bot flies and flesh flies whose larvae are endoparasitic and cause myiases). Several superfamilies contain species whose larvae feed on the flesh of vertebrate hosts, mostly when dead (carrion) but sometimes when still living (causing fly-strike). Oestroid and muscoid larvae are well-adapted for living in moist organic substrates ranging from wet faeces to carrion to living flesh.

The superfamily Oestroidea is characterized by relatively large flies that are not dorsoventrally flattened, their wing veins are not crowded, and the discal medial cell of the wings widens gradually. The superfamily contains 7 families: Calliphoridae (blow flies); Oestridae (bot flies); Polleniidae (cluster flies); Rhinophoridae (woodlouse flies); Sarcophagidae (flesh flies); Tachinidae (parasitic flies); and Ulurumyiidae (McAlpine's fly). The family Oestridae (bot flies, also known as warble flies, heel flies, gad flies) form large hairy adult flies with bulbous heads, small antennae, rudimentary mouthparts, and wings with subcostal veins running parallel to the costa before joining it. Females produce eggs which hatch by discarding an anterodorsal cap, releasing vermiform larvae which are endoparasitic in the tissues (skin, digestive tract or respiratory passages) of vertebrates. The first larval instars have thorn-like spines encircling several segments, while second and third instars have ecdysal (moulting) scars around their spiracular plates (characteristic for the family Oestridae). Over 150 species have been described in some 25 genera in 5 subfamilies: Cephenemyiinae (deer bot flies), Cuterebrinae (New World skin bot flies), Gasterophilinae (stomach bot flies), Hypodermatinae (Old World skin bot flies, warble flies), and Oestrinae (nose and throat bot flies); with one unplaced genus and 3 fossil genera. Representative genera of veterinary significance are tabulated below:

Oestrid subfamily	Genera	Hosts	Strike	Myiasis*
Cuterebrinae (New World skin bot flies)	*Dermatobia*	cattle, humans	primary	Obligate (CU)
Oestrinae (nose and throat bot flies)	*Oestrus*	sheep	primary	Obligate (OC, NP)
Hypodermatinae (Old World skin bot flies, cattle grubs, ox warbles, heel flies)	*Hypoderma*	cattle	primary	Obligate (CU)
Gasterophilinae (stomach bot flies)	*Gasterophilus*	equines	primary	Obligate (GI)

*type of myiasis: CU = cutaneous; GI = gastro-intestinal; NP = naso-pharyngeal; OC = ocular.

The subfamily Cuterbrinae contains 2 genera (*Cuterebra, Dermatobia*) of New World skin bot flies whose larvae parasitize the skin of mammals and some birds. The genus *Dermatobia* contains a single species, *D. hominis* (known as the tropical or American warble fly, human bot fly, or torsalo). The flies have an unusual life-cycle in that females attach their eggs to other live mammalophilic arthropods which act as porters or transporter vectors delivering the eggs to the skin of vertebrate hosts (process also called phoretic transfer or paratenic transport). *Dermatobia* eggs have been shown to be vectored by over 40 species of mosquitoes and muscoid flies, as well as one species of tick. Vertebrate hosts have included humans, wild and domestic animals, companion animals, poultry and aviary birds. *Dermatobia* larvae released from hatched eggs invade subcutaneous tissues causing distress, furuncular lesions, reduced productivity and damaged hides. The flies are restricted in their distribution to the evergreen tropical forests of South and Central America as they require humid conditions for egg survival and moist soil for pupal development.

***Dermatobia* species**	**Hosts**	**Location**	**Clinical signs**	**Distribution**
D. hominis (human bot fly, tropical warble fly, Torsalo, berne, ura, nuche)	Primates: hominid (human), cercopithecid (various monkeys); Carnivora: canid (dog), felid (cat); Artiodactyla: bovid (cattle, buffalo, sheep, goat); Perissodactyla: equid (horse); Galliformes: phasianid (turkey); Piciformes: ramphastid (toucan); and others	skin (wounds)	obligate myiasis (suppurative swellings, severe pain)	Central and South America

Parasite morphology: *Dermatobia hominis* forms 4 different types of morphological stages during its development: eggs; larvae; pupae; and adults. The eggs are ovoid, curved dorsally and flattened ventrally, measuring around 1.0 x 0.5 mm. They are creamy yellow to brown in colour, soft-shelled with a highly sculptured outer chorion, and have a well-developed anterodorsal cap (operculum). Larvae (commonly called bots) grow through 3 instars (L1-3), increasing in size from 1.0-1.5 mm up to 18-24 mm long. They have segmented bodies that are initially white (L1), then change to creamy-yellow (L2-3) and finally darken to brown-black (mature L3). The larvae have distinctive shapes, L1 being drumstick-shaped with elongate thin posterior segments, L2 becoming more robust, and L3 becoming cylindrical-pyriform with thickened body segments that taper posteriorly. The bots lack a sclerotized head capsule, but possess an internal cephalopharyngeal skeleton with large rasping mouthparts (vertically-biting mandibles). The tegumental surface is armed with black thorn-like backward-facing spines that encircle anterior segments, as well as a progressively denser covering of smaller flat plate-like spines (oestrine larvae have few spines, while muscoid larvae lack spines). Larvae breathe through 2 pairs of respiratory spiracles: small inconspicuous anterior spiracles that appear flower-like; and larger posterior spiracles located on a caudal plate that is not surrounded by a distinct peritreme and has 2 sets of 3 parallel slits (calliphorid larvae have 3 slits surrounded by a peritreme, and other oestrid larvae have porous spiracular plates). L2 and L3 also possess ecdysal (moulting) scars around their spiracular plates (characteristic for Oestridae). Pupae are similar in appearance to L3, being ellipsoidal and measuring 20-25 x 5-7 mm, but they are much darker in colour ranging from dark brown to black. Pupae are obtect with faint transverse striations, appendages and spines externally visible, and often exhibiting prominent anterior spiracles (which become everted during pupation). Adult flies eclose through circular caps (like all Cyclorrhapha) rather than through longitudinal slits (like Nematocera, and Brachycera). Adults appear as large hairy flies with stout bodies measuring 10-20 mm long by 4-5 mm wide. They are covered in small setae but generally lack stout bristles. They have a striking bee-like appearance, with yellow-orange heads and legs contrasting with the blue-black thorax and abdomen. Their heads are bulbous and possess both a ptilinal suture and facial lunule (like Muscoidea and Oestroidea but unlike other calypterate flies). The side of the head is broad and pale and contains large orange compound eyes separated by a frons (eyes closer together in males than females) with another 3 simple eyes (ocelli) located on the top of the head. Adults have 2 small antennae located within facial pits, each antenna consisting of 3 dissimilar segments: a short basal scape; a club-like pedicel with a complete dorsal seam; and an anterior flagellum comprising of large dorsal bristle (arista) that is plumose (setate) on the outer side only (arista bare in Oestrinae and Hypodermatinae). Adult flies have vestigial mouthparts and do not feed (similar to other oestrid flies); living instead on reserves built up as voracious larvae. Likewise, their alimentary tract is vestigial but may function to regulate water. The thorax is covered by a shield-like scutum with a posterior lobe-like scutellum. The thorax has a sparse covering of short setae and a vertical row of bristles on the meron (lacking on muscoid flies). The mesothorax has a twice-bent suture and bears a pair of narrow brown wings whose membranes are supported by 6 primary veins [costa (C), subcosta (Sc), radius (R), media (M), cubitus (Cu), and anal (A)], with Sc veins running parallel to the C vein, and the M vein extending directly to the outermost wing. Like all Diptera, the hindwings have been highly reduced to stumpy halteres used to stabilize flight. Like all calyptrate flies, the halteres are covered by hindlobes of the forewings (called squamae or calypters) which are bare (asetate) and large (in all oestrids except gasterophilines). Like all Oestroidea and Muscoidea, adult flies also have bulbous swellings (greater ampulla) underneath the wing bases. The ventral thorax gives rise to 3 pairs of long stout coloured legs, each consisting of 5 segments (coxa, trochanter, femur, tibia, and tarsus) and terminating in a pair of claws with pad-like pulvilli surrounding a central bristle (empodium). The abdomen is often metallic coloured and covered with fine hair. The segments bear lateral spiracles and the terminal segments are modified by genital structures (female pseudovipositor, male aedeagus and claspers). Males have 2 testes joined by vas deferens to a seminal vesicle (with lateral accessory glands) leading to a tubular ejaculatory duct and copulatory aedeagus. Females have 2 ovaries connected by oviducts to a globular uterus (with associated spermatheca and accessory glands) leading to the vulva and the terminal elongated pseudovipositor.

Site of infection: *Dermatobia* larvae are obligate parasites in the skin of warm-blooded vertebrates. They exhibit a broad host specificity, unlike other oestrid flies which have a narrow specificity for a small range of hosts. Infestations have been reported in primates (incl. humans), ungulates (cattle, sheep, goats, equines), carnivores (cats, dogs), and some poultry and aviary birds. They are most commonly encountered in cattle, dogs and humans. Larvae invade subcutaneous layers of the skin at any exposed sites, commonly on the legs, arms, scalp and back. arms, legs, back and scalp. On rare occasions, they have also been found associated with the eyes, mouth, nose and genitalia. Adult flies are not parasitic, but females waylay and pressgang other live arthropods (mosquitoes, muscoid flies and even ticks) into serving as transport vectors for their eggs. The eggs are attached to external surfaces of these vectors who then deliver them to vertebrates when they feed.

Pathogenesis: First-stage larvae (L1) hatched from eggs are able to penetrate vertebrate host skin either by burrowing through intact skin or through hair follicles, insect bites or other pre-existing lesions. The larvae feed using their sclerotized mouthparts to tear and rasp host tissues resulting in the development of a small (2-3 mm) elevated erythematous papule within 24 hours. L1 do not migrate away from the point of entry but they may move deeper into subcutaneous, and sometimes underlying muscular, tissue as they develop through another 2 instars (this is in contrast to other oestrid larvae which migrate away from their point of entry to mature in other tissues). The papule indurates and grows over several weeks into a furuncular (boil-like) lesion up to 10-35 mm in diameter and 5-10 mm high. Furuncles are like micro-abscesses as they are surrounded by granulation tissue (acute and chronic inflammatory cells) and fibrosis. The larvae live in these encapsulated pockets (often referred to as warbles) and create a small central hole (punctum or pore) to the surface through which they breathe and excrete waste. Warbles are evident as non-healing lesions that may

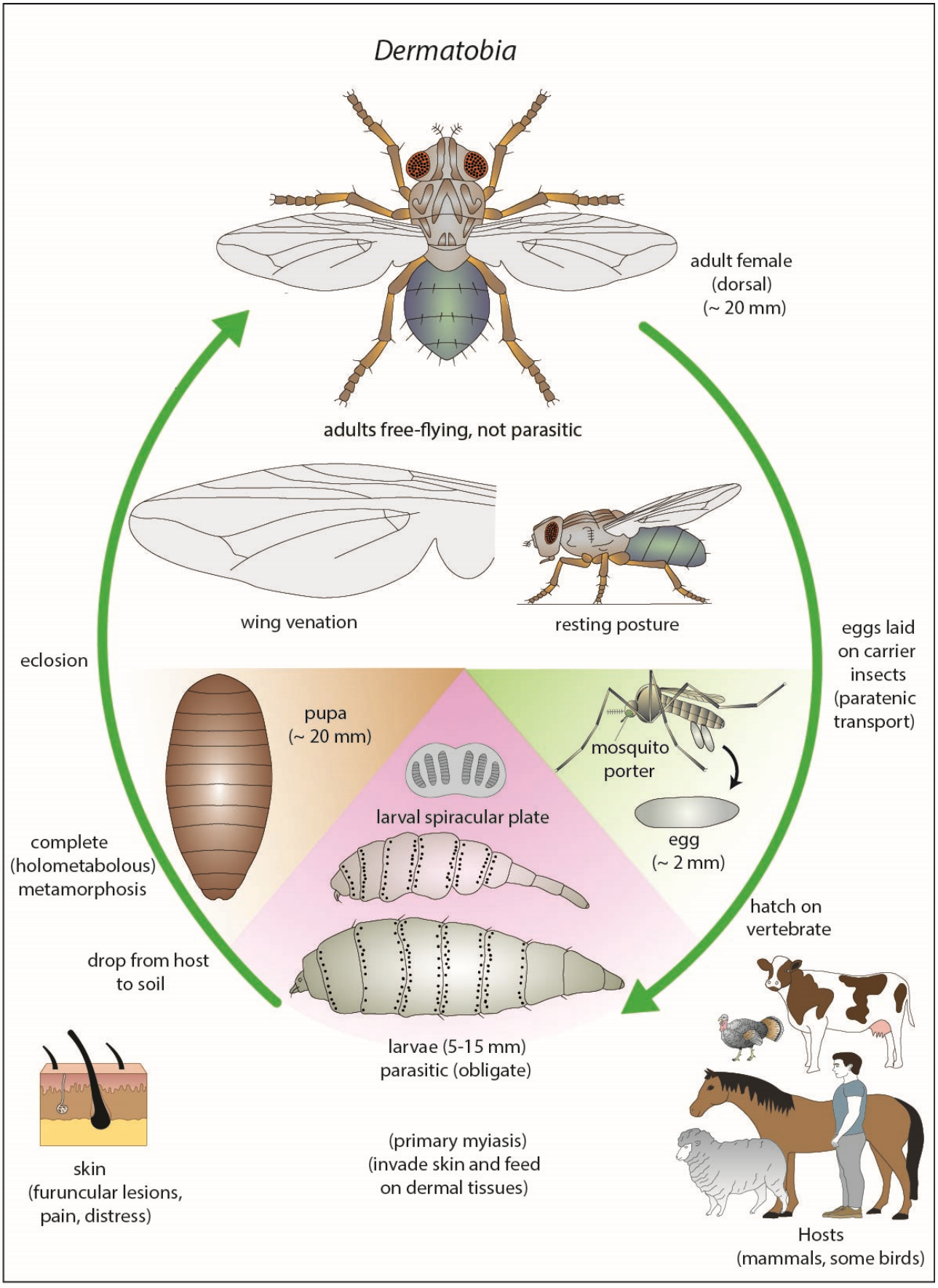
suppurate and weep serosanguinous or seropurulent fluids with intermittent bleeding and fetid odours. They may persist for 6-10 weeks, and sometimes last for up to 3 months. Hosts often become distressed and experience severe acute pain with inflammation and pruritus. Patients may describe a creeping or crawling sensation under the skin, particularly when lesions are covered. Some develop systemic signs such as headache and regional lymphadenopathy. Despite the invasive nature of the wounds, few patients develop secondary bacterial infections which is thought to be due to the bacteriostatic action of larval secretions. When replete, mature L3 move to the surface of the furuncles and leave the wounds dropping to the ground to pupate. Lesions generally resolve spontaneously without overt scarring following removal or emergence of the larvae. On rare occasions, larvae have been associated with eye lesions (opthalmomyiasis), nasal lesions (rhinomyiasis), genital lesions (vaginal myiasis), and even brain lesions (cerebral myiasis where larvae have burrowed through fontanelles in the skull of an infant). In Central America, these bot flies cause a significant problem in cattle (known colloquially as 'warbles'), with reduced meat and milk production and damage to hides.

Developmental cycle and mode of transmission: The life-cycle of bot flies involves holometabolous development in that grub-like larvae undergo complete metamorphic transformation in pupae into winged adults. The adult flies are free-flying but do not feed or seek vertebrate hosts on which to lay eggs. Instead, the females have adopted a unique means of ensuring their eggs come into contact with vertebrate hosts. They capture other blood-feeding arthropod ectoparasites and deposit small batches of 6-30 eggs on their external surfaces (abdomen and legs), securing them with water-resistant adhesive secretions. These arthropods are then released and continue their own cycles which involves locating and feeding on blood from vertebrates. The bot fly eggs embryonate over 5-15 days and are triggered to hatch while the arthropod is feeding in response to increased temperature and moisture levels associated with vertebrate hosts. The released larvae come into contact with vertebrate skin and burrow into subcutaneous tissues ultimately causing furuncular lesions. Because the eggs are effectively passively carried to vertebrates, the arthropods are considered to be mechanical transport vectors (porters) for the bot flies. This process is known variously as paratenic transport or phoretic transfer. *Dermatobia* eggs have been shown to be vectored by over 40 species of mosquitoes (mostly day-biting culicids), filth flies (muscids), blow flies (calliphorids), horse flies (tabanids) and even some hard ticks (ixodids). The use of numerous types of transporter vectors, each with different host specificities, is thought to contribute to the broad host range of *Dermatobia* for mammals and birds. Similarly, *Dermatobia* infestations are not site specific, but will occur on any skin available to the porter. On occasion, when gravid female bot flies cannot find a porter, eggs have been shown to be oviposited on vegetation or clothes hung outside to dry, and the larvae emerge if they come into contact with vertebrate hosts. Larvae usually penetrate the skin within one hour but are able to survive for several days before entry. They develop in subcutaneous tissues and do not wander to other sites to mature (unlike other oestrid larvae which migrate extensively). The larvae develop through 3 instars (L1-3) over 4-8 weeks, but may sometimes persist up to 10-18 weeks. Mature L3 then emerge from the wounds, drop to the ground and burrow into the soil forming puparia by hardening of their teguments. Pupation varies considerably in duration, ranging from 3-18 weeks depending on prevailing environmental conditions (longer in cooler climates). Cuterebrine bot flies in temperate zones typically over-winter as diapausing pupae (while other oestrids over-winter as larvae in their hosts). Adult flies emerge from the pupae and take flight in search of mates and arthropod hosts for their eggs. Adults do not feed but live on energy stores accumulated as larvae. Female flies are autogenous and may produce eggs soon after emergence and mating. Adults live for 4-9 days and females may produce up to 800 eggs in their lifetimes. *D. hominis* requires high relative humidity for eggs to survive and moist soil for pupae to develop. Infestations are generally restricted to the humid tropical forests in Central and South America, occurring along margins of cool moist secondary forests in hilly and lowland regions (including abundant coffee plantations).

Differential diagnosis: Infestations may be suspected on the basis of clinical grounds (painful furuncular lesions, warbles) and patient history (residence of travel to endemic regions). However, furuncles are often misdiagnosed as infected arthropod bites, abscesses or tropical ulcers in travelers returning from endemic countries. Diagnosis is made by the direct detection of larvae within wounds, their collection (by careful extraction) and their identification based on morphological characters (notably, spiracles, mouth hooks and tegumental spines). Medical imaging technologies may be used to assist the discrimination of larvae within wounds, usually ultrasonography. Modern molecular biological techniques have been used to characterize isolates by polymerase chain reaction (PCR) amplification of nuclear (ribosomal DNA) and mitochondrial (cytochrome oxidase) gene sequences.

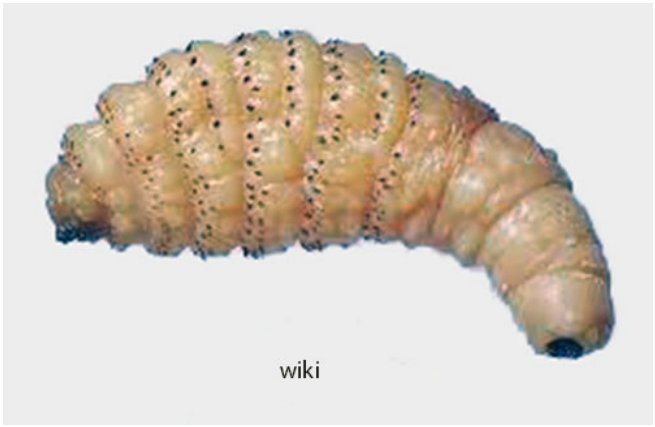
Treatment and control: It is recommended that furuncular wounds be treated and larvae extracted to prevent secondary infections (by bacteria or other fly larvae), abscess formation, cellulitis, regional lymphadenopathy, malaise and fever. Larvae may be removed by careful manipulation with forceps, tweezers or even venom extraction syringes, but the bots are difficult to extract due to their bulbous bodies and backwardly-facing spines. Occlusive dressings are often used to cover the central pores in the warbles through which the larvae breathe using their posterior spiracles. This brings the larvae closer to the surface and may suffocate them so they are easier to extract. A range of oil- or fat-based dressings have been used, including petroleum jelly, vaseline, mineral or vegetable oil, liquid paraffin, beeswax, bacon fat, butter, and even chewing gum, adhesive tape, fingernail polish and raw meat poultices. The central punctum usually needs to be enlarged and lidnocaine and epinephrine can be flushed into the wound to cause local contraction. In many cases, the wound may need to be incised and debrided under local anaesthesia to remove the larvae, taking care not to damage them as residual fragments may cause inflammatory and/or allergic reactions. Recent studies have indicated that the application of macrocyclic lactones (avermectin, ivermectin) to wounds in awkward or inaccessible sites resulted in the spontaneous emigration of *D. hominis* bots. More typically, chemical insecticides are used prophylactically to prevent infestations in livestock and pets by targeting the haematophagous arthropod porters of bot fly eggs, as well as the emergent larvae. Conventional

insecticides may be applied as topical sprays, dips, pour-ons or impregnated tags, including organochlorines (toxaphene, dichloro-diphenyl-trichloroethane (DDT), lindane), organophosphates (crufomate, trichlorfon, fenthion), and salicylanilides (closantel), although topical or systemic applications of macrocyclic lactones (ivermectin, abamectin, doramectin) are now widely used. Insecticides should be applied at regular intervals depending on their residual activity and duration of protection. Humans working in endemic regions may benefit by applying insect repellents (such as diethyltoluamide (DEET)) to skin or clothing, wearing long-sleeved clothing, ironing clothing that has been hung outside to kill any deposited eggs, and erecting barriers (screens, curtains, nets) around living and sleeping quarters. Maintaining good hygiene and the prompt treatment of any wounds with stringent antiseptics or alcohol will assist in the prevention of infestations.


Dermatobia
adult female
(dorsal)
(~ 20 mm)
adults free-flying, not parasitic
wing venation
resting posture
eggs laid
on carrier
insects
(paratenic
transport)
eclosion
pupa
(~ 20 mm)
mosquito
porter
larval spiracular plate
egg
(~ 2 mm)
complete
(holometabolous)
metamorphosis
hatch on
vertebrate
drop from host
to soil
larvae (5-15 mm)
parasitic (obligate)
skin
(furuncular lesions,
pain, distress)
(primary myiasis)
(invade skin and feed
on dermal tissues)
Hosts
(mammals, some birds)

Dermatobia adult

Dermatobia young larva



Dermatobia mature larva

Dermatobia pupa