

Musca
(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). Muscid flies include many non-biting and biting genera, the former being nuisances and the latter being blood-feeders. Most species are synanthropic (closely associated with humans) and they breed in all types of organic waste. Two subfamilies are recognized: muscines (house flies, bush flies, face flies) with sucking mouthparts adapted to feeding on decaying organic matter; and stomoxines (stable flies, horn/buffalo flies) with elongate biting mouthparts adapted to blood feeding. House flies (*Musca* spp.) have been shown to serve as mechanical vectors for an extraordinary range of infectious diseases in humans, most being enteric diseases occasioned by faecal contamination.

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: Muscidae (house/bush/stable/buffalo flies, nuisance flies, synanthropic (associated with human activity))
Subfamily: Muscinae (with sucking mouthparts adapted to feeding on decaying organic matter)
Genus: *Musca* (pests of mammals)
Species: various species cause annoyance

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 Hemipteroidea (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 arista, 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 myiasis) (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 arista), 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 ptilinal suture and sclerotized lunule); and the Aschiza (hover flies lacking a frontal suture and lunule). Within the Schizophora, 2 sections are recognized: the Calyptratae (comprising flies with calypters covering the halteres, large squamae, a strong thoracic suture and well-defined grooves on the antennal pedicels); and the Acalyptratae (without

covering calypters, small squamae, a weak thoracic suture and no pedicel grooves). Calypterae 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 myiasis).

The superfamily Muscoidea contains 4 families: Muscidae (house flies), Fanniidae (latrine flies), Scathophagidae (dung flies) and Anthomyiidae (anthomyiid flies). The family Muscidae contains robust flies with plumose arista and wings where vein A2 is not strongly curved (unlike latrine flies). The family contains both free-living flies, some of which are nuisance pests of livestock and humans, as well as blood-sucking flies feeding on vertebrates. Over 4,200 species have been described in some 190 genera classified into 9-10 subfamilies: Achanthipterinae, Azeliinae, Coenosinae, Cyrtoneurinae, Dichaetomyiinae, Muscinae, Mydaeinae, Phaoniinae, and Reinwardtiinae; with another 58 unplaced genera and several fossil genera. Alternatively, some authorities recognize 2 tribes (Muscini and Stomoxyini) in the subfamily Muscinae, some have elevated the tribe Stomoxyini to subfamily status (Stomoxinae), while others have demoted the subfamilies Azeliinae and Reinwardtiinae to tribes (Azelini and Reinwardtiini) in the subfamily Muscinae].

Subfamily	Genera	Hosts	Site	Transmission
Muscinae (with sponging mouthparts)	<i>Musca</i>	mammals,	nonparasitic	nonparasitic
Stomoxinae (with biting mouthparts)	<i>Stomoxys</i>	mammals	skin	direct
	<i>Haematobia</i>	bovines	skin	direct

The subfamily Muscinae contains many species of free-living flies that feed on decaying organic matter, some feeding on secretions from animals. The subfamily contains 17-22 genera (including *Musca*) which are nuisance flies to various animal and human populations around the world as well as mechanical (and sometimes biological) vectors for various infectious diseases (including mastitis, conjunctivitis, anthrax, enteric bacteria/viruses, and helminths). The genus *Musca* (syn. *Byomya*, *Eumusca*, *Plaxemya*) contains over 150 species classified in 10 subgenera. They have been afforded many common names often associated with behavioural or ecological traits, including house-fly, face-fly, bazaar-fly, or bush-fly. Adults feed by sponging up wet secretions at the mouth, nostrils, eyes, teats, or the edges of wounds, some species using a ring of prestomal teeth at the end of the labellum to scrape the skin surface to yield exudates. They annoy a wide variety of domestic and wild animals, sometimes causing bizarre avoidance behaviours that may result in self-trauma but also deplete energy reserves and interfere with feeding. Many species are also synanthropic and exploit food and habitats created by human activities, notably agriculture, housing, garbage and waste disposal.

<i>Musca</i> species (regional exemplars)	Host preferences	Clinical signs (vectorial capacity)	Distribution
<i>M. autumnalis</i> (face fly)	wild and domestic animals (esp. cattle, sheep, goats, pigs, horses, camels), humans	annoyance (mechanical vectors for keratoconjunctivitis (pink eye)) (intermediate hosts of <i>Parafilaria</i> and <i>Thelazia</i>)	Eurasia, Africa, North America
<i>M. crassirostris</i>	wild and domestic animals, humans	annoyance (mechanical vectors for mastitis, conjunctivitis, anthrax, enteric bacteria/viruses, helminth eggs)	Mediterranean
<i>M. domestica</i> (house fly, typhoid fly)	wild and domestic animals (esp. cattle, sheep, goats, pigs, horses, camels), humans	annoyance (mechanical vectors for mastitis, conjunctivitis, anthrax, enteric bacteria/viruses, helminth eggs) (intermediate hosts for nematodes <i>Habronema/Raillietina</i> spp.)	worldwide
<i>M. sorbens</i> (bazaar fly)	wild and domestic animals (esp. cattle, sheep, goats, pigs, horses, camels), humans	annoyance (mechanical vectors for conjunctivitis, enteric bacteria/viruses)	Africa, Orient
<i>M. vetustissima</i> (bush fly)	wild and domestic animals (esp. cattle, sheep, goats, pigs, horses, camels), humans	annoyance (mechanical vectors for conjunctivitis, enteric bacteria/viruses)	Australia, Africa

Full species list (compilation of several on-line data-bases)

Musca species	Subgenus
<i>M. aethiops</i>	<i>Eumusca</i>
<i>M. afra</i>	<i>Byomya</i>
<i>M. albina</i>	<i>Lissosterna</i>
<i>M. alpesa</i>	<i>Philaematomyia</i>
<i>M. amita</i>	<i>Eumusca</i>
<i>M. arcuata</i>	Unassigned
<i>M. asiatica</i>	Unassigned
<i>M. ausus</i>	Unassigned
<i>M. bakeri</i>	<i>Viviparomusca</i>
<i>M. bezzii</i>	<i>Viviparomusca</i>
<i>M. bicolor</i>	Unassigned
<i>M. biseta</i>	<i>Byomya</i>
<i>M. bohemica</i>	Unassigned
<i>M. cadaverum</i>	Unassigned
<i>M. calieva</i>	Unassigned
<i>M. calleva</i>	<i>Musca</i>
<i>M. capensis</i>	<i>Byomya</i>
<i>M. carinata</i>	Unassigned
<i>M. cassara</i>	<i>Byomya</i>
<i>M. chibcha</i>	Unassigned
<i>M. chingaza</i>	Unassigned
<i>M. ciliata</i>	Unassigned
<i>M. conducens</i>	<i>Byomya</i>
<i>M. confiscata</i>	<i>Byomya</i>
<i>M. conflu</i>	Unassigned
<i>M. conica</i>	Unassigned
<i>M. continua</i>	Unassigned
<i>M. convexifrons</i>	<i>Viviparomusca</i>
<i>M. costalis</i>	Unassigned
<i>M. costata</i>	Unassigned
<i>M. craggi</i>	<i>Eumusca</i>
<i>M. crassipes</i>	Unassigned
<i>M. crassirostris</i>	<i>Philaematomyia</i>
<i>M. cuprea</i>	Unassigned
<i>M. curpraria</i>	Unassigned
<i>M. curviforceps</i>	<i>Musca</i>
<i>M. dasyops</i>	<i>Byomya</i>
<i>M. divisa</i>	Unassigned
<i>M. doclea</i>	Unassigned
<i>M. domestica</i>	<i>Musca</i>
<i>M. dorsalis</i>	Unassigned
<i>M. dorsomaculata</i>	Unassigned
<i>M. dubia</i>	Unassigned
<i>M. elatior</i>	<i>Philaematomyia</i>
<i>M. embera</i>	Unassigned
<i>M. emdeni</i>	Unassigned
<i>M. equinoactialis</i>	Unassigned
<i>M. ethiopica</i>	<i>Byomya</i>
<i>M. fasciata</i>	Unassigned
<i>M. femorata</i>	Unassigned
<i>M. fergusonii</i>	Unassigned
<i>M. flavicans</i>	Unassigned
<i>M. fletcheri</i>	<i>Eumusca</i>
<i>M. formosana</i>	<i>Viviparomusca</i>
<i>M. freedmani</i>	<i>Byomya</i>

<i>M. fuscipennis</i>	Unassigned
<i>M. gabonensis</i>	Unassigned
<i>M. harpyia</i>	Unassigned
<i>M. hebes</i>	Unassigned
<i>M. heidia</i>	<i>Eumusca</i>
<i>M. hervei</i>	<i>Eumusca</i>
<i>M. hirsute</i>	Unassigned
<i>M. hugonis</i>	<i>Byomya</i>
<i>M. hydropica</i>	Unassigned
<i>M. iguaque</i>	Unassigned
<i>M. illingworthi</i>	<i>Viviparomusca</i>
<i>M. incerta</i>	Unassigned
<i>M. inferior</i>	<i>Ptilolepis</i>
<i>M. interrupta</i>	Unassigned
<i>M. katio</i>	Unassigned
<i>M. khofarae</i>	Unassigned
<i>M. laemica</i>	Unassigned
<i>M. lamosca</i>	Unassigned
<i>M. larvipara</i>	<i>Viviparomusca</i>
<i>M. lasiopa</i>	<i>Eumusca</i>
<i>M. lasiophthalma</i>	<i>Byomya</i>
<i>M. leucocephala</i>	Unassigned
<i>M. liberia</i>	<i>Byomya</i>
<i>M. lindneri</i>	<i>Byomya</i>
<i>M. lothari</i>	<i>Eumusca</i>
<i>M. lucidula</i>	<i>Byomya</i>
<i>M. lusoria</i>	<i>Eumusca</i>
<i>M. maculipennis</i>	Unassigned
<i>M. magdalena</i>	Unassigned
<i>M. malaisei</i>	<i>Setimusca</i>
<i>M. mallochi</i>	Unassigned
<i>M. matilia</i>	Unassigned
<i>M. meruensis</i>	<i>Philaematomyia</i>
<i>M. moneta</i>	Unassigned
<i>M. munroi</i>	<i>Eumusca</i>
<i>M. negriabdomina</i>	Unassigned
<i>M. neustriiae</i>	Unassigned
<i>M. nevilli</i>	<i>Eumusca</i>
<i>M. nora</i>	Unassigned
<i>M. obscura</i>	Unassigned
<i>M. osiris</i>	<i>Plaxemya</i>
<i>M. patersoni</i>	<i>Eumusca</i>
<i>M. pattoni</i>	<i>Byomya</i>
<i>M. pellucens</i>	Unassigned
<i>M. picea</i>	Unassigned
<i>M. pijao</i>	Unassigned
<i>M. pilifacies</i>	<i>Plaxemya</i>
<i>M. pilosa</i>	Unassigned
<i>M. placida</i>	Unassigned
<i>M. planiceps</i>	<i>Byomya</i>
<i>M. polisma</i>	Unassigned
<i>M. polita</i>	Unassigned
<i>M. porce</i>	Unassigned
<i>M. procedo</i>	Unassigned
<i>M. pseudocorvina</i>	<i>Eumusca</i>
<i>M. quimbaya</i>	Unassigned

<i>M. rapax</i>	Unassigned
<i>M. recedans</i>	Unassigned
<i>M. recurro</i>	Unassigned
<i>M. redians</i>	Unassigned
<i>M. rubripes</i>	Unassigned
<i>M. ruficrus</i>	Unassigned
<i>M. rufiventris</i>	Unassigned
<i>M. santoshi</i>	<i>Pseudosetimusca</i>
<i>M. scutellaris</i>	Unassigned
<i>M. segmentaria</i>	Unassigned
<i>M. seniorwhitei</i>	<i>Eumusca</i>
<i>M. setulosa</i>	<i>Eumusca</i>
<i>M. somalorum</i>	<i>Eumusca</i>
<i>M. sorbens</i>	<i>Byomya</i>
<i>M. spangleri</i>	<i>Byomya</i>
<i>M. spec</i>	Unassigned
<i>M. splendens</i>	<i>Viviparomusca</i>
<i>M. stabulans</i>	Unassigned
<i>M. striatacta</i>	Unassigned
<i>M. stuckenbergi</i>	Unassigned
<i>M. suffusa</i>	Unassigned
<i>M. sumapaz</i>	Unassigned

<i>M. sutagao</i>	Unassigned
<i>M. tahitiensis</i>	Unassigned
<i>M. tempestatum</i>	<i>Byomya</i>
<i>M. tempestiva</i>	<i>Byomya</i>
<i>M. terraereginae</i>	Unassigned
<i>M. tibetana</i>	<i>Plaxemya</i>
<i>M. transvaalensis</i>	<i>Byomya</i>
<i>M. turbida</i>	Unassigned
<i>M. ugandae</i>	<i>Eumusca</i>
<i>M. varia</i>	Unassigned
<i>M. ventrosa</i>	<i>Byomya</i>
<i>M. vermileo</i>	Unassigned
<i>M. vespasianus</i>	Unassigned
<i>M. vetustissima</i>	Unassigned
<i>M. vicina</i>	Unassigned
<i>M. villeneuveii</i>	<i>Eumusca</i>
<i>M. violacea</i>	Unassigned
<i>M. vitripennis</i>	<i>Byomya</i>
<i>M. wittweri</i>	<i>Byomya</i>
<i>M. xanthomelaena</i>	Unassigned
<i>M. xanthomelas</i>	<i>Eumusca</i>

Parasite morphology: Muscid flies form 4 different types of morphological stages during their developmental cycles: namely, eggs, larvae (3 instars), pupae and adults (male and female). *Musca* eggs are creamy white and typically elongate-ellipsoid measuring from 1-3 mm long, most being concave dorsally with 2 ribs forming hatching pleats, and some with a short anterior respiratory stalk (e.g. *Musca autumnalis*). Larval stages (known as maggots) are creamy white-yellow and have elongate segmented bodies with a pointed anterior end and a blunted posterior end (whereas oestroid larvae are more cylindrical). Larvae develop through 3 instars (L1-3) growing up to 7-12 mm long. The head bears an anterior mouth with mouth hooks but is otherwise highly reduced lacking eyes and with minute papilla-like antennae. The head lacks a sclerotized capsule but is supported internally by a sclerotized cephalo-pharyngeal skeleton. Larvae do not have legs, but the 8 abdominal segments have ventral patches of tiny transverse spines forming creeping welts. All larvae breathe using respiratory spiracles: one anterior pair (absent in L1) located laterally on the first thoracic segment (and apparent as small branched tubercles); and a second larger posterior pair located dorsally on caudal abdominal plates (each consisting of a sclerotized peripheral ring (peritreme), 2-3 straight-sinuuous slit-like openings for gas exchange (2 slits in L1-2, and 3 slits in L3) and an ecdysal scar from a previous moult). In muscid larvae the slits slant towards the midline, while in sarcophagids the slits slant away from the midline [in contrast to oestrid larvae which have porous plates]. When L3 mature, the tegument contracts and hardens to form a cylindrical barrel-shaped puparium measuring from 2-8 mm long, varying in colour from white-yellow to red-brown and sometimes black, usually darkening with age. Inside the puparium, a pupa forms leaving larval structures (spiracles and cephalo-pharyngeal skeleton) embedded in the puparial case. Adults are brownish grey-black flies 5-10 mm long, often with dark longitudinal stripes on the thorax (called vittae) and dark spots on abdomen. Their bodies have 3 conspicuous tagma: a short broad head, stout thorax and ellipsoidal abdomen. The head possesses both a ptilinal suture and facial lunule (like all Muscoidea and Oestroidea, but unlike other calyptates), 2 large red-brown compound eyes located laterally and separated by a frons bearing 3 small ocelli, and a distinctive pair of anterior antennae (each composed of a small basal scape and a club-like pedicel from which emerges a bilaterally-plumose arista (single undivided flagellum bearing fine setae)). All *Musca* spp. are liquid feeders that have sponging rather than biting mouthparts that project downwards and are flanked by strong oral bristles (vibrissae). The proboscis consists of 3 major elements: a basal rostrum flanked by short setate palps; a cylindrical haustellum housing an anterior labrum, slender hypopharynx and sheath-like labium; and a terminal 2-lobed labellum lined with prestomal teeth and pseudotracheae (rows of fine setae). Liquids ingested by strong pharyngeal muscular action (cibarial pump) pass into a tubular oesophagus and proventriculus leading to the digestive midgut. Dilute fluids like plant sugars may be shunted for temporary storage into a saccular diverticulum, the contents of which may be regurgitated and reingested to aid evaporation. Waste material passes through the hindgut (with excretory Malpighian tubules) to the rectum (with expandable ampulla) and terminal anus. Fly specks that collect on feeding and resting sites therefore consist of both fly vomit and faeces. The pyriform thorax is usually dull with 2-4 dark longitudinal stripes, 2 pairs of respiratory spiracles (anterior mesothoracic and posterior metathoracic), and a bare hypopleuron (without bristles or setae in muscids). The mesothorax bears 2 long wings, with membranes supported by 6 primary veins [costa (C), subcosta (Sc), radius (R), media (M), cubitus (Cu), and anal (A)], with vein A1 vanishing before reaching the wing margin, vein A2 not strongly curved (unlike latrine flies), and vein M1 having a sharp forward bend. Like all Diptera, the hindwings are highly reduced to a pair of stumpy halteres used to stabilize flight. Like other calyptate flies, the halteres are covered by calypters (posterobasal wing lobes), but only the Muscoidea and Oestroidea have a bulbous greater ampulla below the wing base. The ventral thorax is the point of attachment for 3 pairs of legs: each consisting of 5 segments (coxa, trochanter, femur, tibia, and tarsus); and each terminating in a pair of claws with 2 pads (pulvilli) surrounding several central bristles (empodium). The abdomen is often dull

yellow-brown, sometimes with a longitudinal dark band, sometimes chequered light-dark patterns, and sometimes with lighter yellow sides. Segmentation is often reduced from 10-12 to as few as 5 visible segments due to posterior segments being modified by terminalia (anal cerci in both sexes, claspers and retractable aedeagus in males, tubular telescopic ovipositor in females). Males have 2 testes with vas deferens leading to a seminal vesicle (with lateral accessory glands) and a tubular ejaculatory duct connected to the aedeagus in the genital pouch. Females have 2 ovaries joined by oviducts to a globular uterus (with associated spermatheca and accessory glands) leading to the vulva and posterior ovipositor.

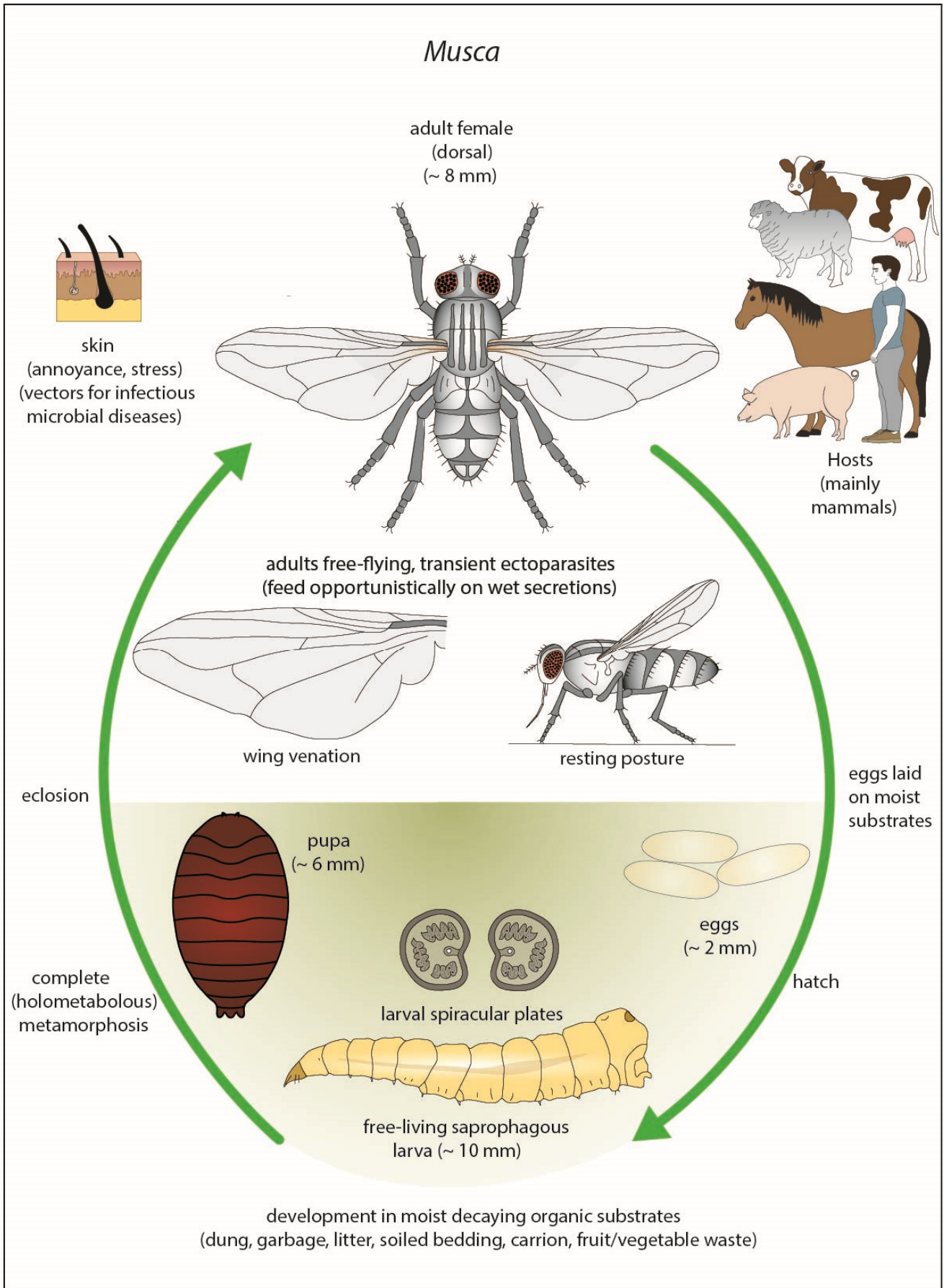
Site of infection: *Musca* spp. are non-biting filth flies that feed on liquids and suspensions both off hosts (plants nectar, honeydew) and on hosts (surface secretions (sweat, tears, snot, saliva), excreta (urine, faeces) and wounds). Their favoured feeding sites are moist areas due to discharges around the eyes, nose, mouth, lips, perineum, vulva, and preputium or urethral process of the penis. They are not highly host specific but will feed opportunistically from a range of vertebrate hosts. However, many species are attracted to large mammals as sources of food as well as faeces for oviposition, and have attained many regional common names suggesting some degree of site or host specificity (such as face fly, house fly, bazaar fly, bush fly).

Pathogenesis: Adult flies scavenge on host surface secretions using their sponging mouthparts, essentially by a process of salivating, scrubbing and sucking (they do not penetrate skin). The labellum is opened out and pressed against the substrate releasing saliva laden with enzymes. The labellum is then opened and closed to scarify food into the saliva, with the resultant suspension being drawn along the pseudotracheae into the food canal. They will feed on sweat, tears, lachrymal secretions, snot, saliva, mucus, and serous exudates (sometimes even blood but only if it is seeping from wounds). When not feeding, they will rest on solid structures which become speckled with fly spots (vomit and faeces). Filth flies are usually considered to be minor nuisances causing annoyance to their hosts, but dense clusters may cause severe irritation and disturbance (fly worry) resulting in energy-consuming avoidance behaviours (swatting, shaking, twitching) and reduced feeding efficiency with lowered weight gain and decreased performance. Several species have occasionally been associated with secondary myiasis when their larvae invade host tissues, notably undressed wounds, eyes with excessive lacrimation, urogenitalia associated with urine-soaked clothing, and even the gastro-intestinal tract (when larvae are either ingested in contaminated food or undergo retro-infection through the anus when attracted by faecal soiling). Filth flies have been implicated in the transmission of many infectious diseases, predominantly by acting as mechanical vectors (or paratenic transport hosts) for various bacteria, viruses, protozoa and helminths, either by carrying infectious stages on their surfaces (hairy feet, bodies and mouthparts) or by passing them in vomitus or faeces. Transmission may occur by direct skin contact or by food and drink contamination. Filth flies live and breed in or near dung heaps and other decomposing materials, so they have frequently been found to transmit enteric pathogens causing diarrhoea (including bacillary and amoebic dysentery, salmonellosis, shigellosis, escherichiosis, typhoid, cholera, cryptosporidiosis, giardiasis, hepatitis A, Cocksackie virus, and enteric cytopathogenic human orphan (ECHO) viruses) as well as tuberculosis, trachoma eye disease and pyogenic cocci in humans, and anthrax, mastitis and keratoconjunctivitis (pink-eye) in cattle. Several species have also been found to carry the eggs or larvae of several helminths, including nematodes (*Ascaris*, *Enterobius*, *Trichuris* in humans, *Habronema*, *Draschia*, *Thelazia* and *Parafilaria* in ungulates) and cestodes (*Hymenolepis*, *Railletina* and *Choanotaenia* in mammals and birds).

Developmental cycle and mode of transmission: Muscid flies exhibit holometabolous development where grub-like larvae undergo complete metamorphosis in pupae to form adult winged flies. Females are oviparous and lay eggs in batches of 50-150 eggs every 2-5 days under ideal conditions (smaller batches for face flies, and longer intervals in colder conditions). The eggs are deposited in a wide variety of decaying organic substrates, so long as they are moist enough to support aerobic microbial fermentation. Substrates common around human habitations and livestock enclosures include animal dung, manure piles, open privies, garbage dumps, rotting feedstuffs, soiled bedding, poultry litter, carrion, and fruit and vegetable wastes. Different *Musca* spp. may show some habitat preferences, such as *M. autumnalis* and *M. vetustissima* for cattle dung, while others, including *M. domestica*, lay eggs in any decaying material. Eggs hatch within 12 hours releasing larvae which are saprophagous and feed by filtering bacteria, yeasts and other small suspended particles in the semi-liquid habitats (cf. larvae of other muscid genera may also be facultative predators). Larvae grow through 3 instars (L1-3) over 3-5 days before the mature L3 burrows into the adjacent ground and forms a puparium containing a pupa. Pupation generally takes from 2-6 days, but may be longer (20 days or more) in colder conditions. Some species may also over-winter in the pupal stage, with adults only emerging with warmer weather. Adults eclose from pupae through a circular cap (and not through a longitudinal slit like Nematocera and other Brachycera). Adult flies are strong fliers and most species are active during daylight hours preferring direct sunshine over shaded enclosures, although anthropophilic species will invade households and barns. The adults locate food sources using chemical and visual senses (olfaction and sight) and feed to obtain nutrients for survival and reproduction. The females of most species are anautogenous and require protein meals to complete their first gonotrophic (ovarian) cycles. Mating takes place after males resting on vantage points intercept passing females which then store enough sperm to remain fertile for life. Eggs are produced over several days and oviposited in batches, before the next gonotrophic cycle begins. Adult flies live for around 14 days, although some species may overwinter as adults in sheltered hibernacula such as tree bark or building crevices. The whole life-cycle may be completed in as little as 7-10 days, but usually takes longer (40-50 days) at lower temperatures. Most species are multivoltine and have multiple generations each year, up to 12 in temperate regions, but up to 20 in tropical regions. Nonetheless, most species exhibit seasonal patterns in abundance which coincide with warm moist conditions suitable for larval habitats.

Differential diagnosis: Infestations by nuisance filth flies may be evident by the disturbance caused by flies alighting on moist areas of skin (around eyes, mouth and perineum), but can only be confirmed by capturing adults for microscopic examination and identification. On the rare occasions when larval myiasis may be attributed to filth flies, diagnosis has been made by careful examination of larval instars for their key morphological characteristics. Molecular biological techniques have been used to characterize species and examine phylogenetic relationships following the amplification by polymerase chain reaction (PCR) of nuclear and mitochondrial genes - indeed the complete genomes have been sequenced for several *Musca* spp.

Treatment and control: Animals may be protected from some fly worry by the topical application (sprays, dusts, some pour-ons) of various insecticides (organochlorines, organophosphates, pyrethroids), although they are often limited in effect as filth flies spend little time in contact with their hosts. Many insecticides do not have long-lasting activity and need to be applied regularly, while those with long residual activity may be used not only on animals but also on fly resting places in the immediate environment (building walls, ceilings and fixtures). The most effective formulations appear to be sprays combining the pyrethroid permethrin with synergists (piperonyl butoxide, bicycloheptene dicarboximide) and repellents (diethyltoluamide, DEET). There are mounting concerns about the over-use of insecticides in the environment due to the potential for the emergence of insecticide-resistance as well as their persistence and detrimental impacts on natural ecosystems. Adult flies may also be killed in closed spaces by knockdown aerosols, sticky traps, light traps, and insecticide baits (using sugar or pheromone attractants). Fly repellents (such as diethyltoluamide, DEET) may also be used for personal protection, either applied directly to the skin or onto clothing. Indoor enclosures can also be protected by erecting barriers (screens, curtains and nets) around entry points, and individuals may be protected by covering bare skin with long-sleeved clothing and wearing fly veils or other headwear with fly deterrents (dangling strings). Controlling filth fly populations is of enormous public health significance as they may transmit so many infectious diseases, but regrettably basic sanitation, waste management, and animal husbandry practices are often not of high enough standard in many rural and peri-urban situations, and are severely compromised in times of drought, flood, famine and war. The removal of free-standing organic waste (human and animal faeces, manure piles, rotting vegetable matter, garbage) will reduce available larval habitats and help manage fly populations. The use of chemical larvicides on organic waste is often discouraged due to environmental concerns and their potential effects on the many natural predators, parasitoids and parasites of fly larvae and pupae (including mites, beetles, wasps and other flies). Many countries utilize integrated pest management strategies involving improved sanitation, farm and household management, food and milk hygiene, and the judicious use of insecticides and repellents. Education campaigns designed to make populations aware of food, water, animal and personal hygiene may assist in reducing the transmission of infectious diseases.





Musca adult



Musca adult



Musca eggs



Musca larva



Musca larval spiracles



Musca pupae