Lucilia, Calliphora
(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). Calliphorids (blow flies) are not parasitic as adults but their larvae help destroy carcasses and may cause traumatic cutaneous myiases (flystrike, screwworm infestation) in live mammals. Adult flies are large and often metallic in colour. Eggs laid on hosts release larvae which may penetrate the skin to feed on subcutaneous tissues. Most species are facultative invaders causing primary, secondary or tertiary strike, although several (notably screwworms) are obligate parasites. Larvae of *Lucilia* and *Calliphora* species are primary or secondary facultative invaders and cause serious flystrike in domestic livestock.

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:	Calliphoridae (blow flies, often metallic, larvae cause myiases (flystrike/screwworm infestation))
Genus:	*Lucilia* (primary) (parasitic on skin/subcutaneous tissues of mammals)
Genus:	*Calliphora* (secondary) (parasitic on skin/subcutaneous tissues of mammals)
Species:	various species cause myiasis (flystrike) in sheep)

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 contains 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, written as two words to distinguish them from other fly-like insects with compound names such as dragonflies); Oestridae (bot flies); Polleniidae (cluster flies); Rhinophoridae (woodlouse flies); Sarcophagidae (flesh flies); Tachinidae (parasitic flies); and Ulurumyiidae (McAlpine's fly). The family Calliphoridae is characterized by blow flies with metallic iridescent bodies (blue-black, violet-blue, green), strong bristles, well-developed mouthparts and antennae, and weak post-scutellum. The family contains over 1,100 species of blow flies, carrion flies, bluebottles, greenbottles and cluster flies which help destroy carcases, although many species have been implicated in larval myiasis ('flystrike') in living animals. Most invasions are facultative (opportunistic) causing primary, secondary or tertiary flystrike (categorized according to whether they initiate strike or occur later), although several species (notably screwworms) are obligate parasites whose larvae must develop in flesh. The larvae of most blow fly species are not selective feeders and they exhibit broad host specificity, usually for mammals, occasionally birds and less commonly amphibians and reptiles. Myiasis-causing flies have been found worldwide, particularly in temperate and tropical regions with large domestic livestock populations, but also in cooler regions where wildlife abound. Some 75 genera have been described in 11 subfamilies: Ameniinae, Aphyssurinae, Auchmeromyiinae, Calliphorinae, Chrysomyinae, Helicoboscinae, Melanomyinae, Mesembrinellinae, Phumosinae, Rhiniinae and Toxotarsinae, with another 14 unplaced genera and several fossil genera. The subfamily Chrysomyinae comprises blow flies distinguished by setose stem veins, while members of the subfamily Calliphorinae are characterized by adult flies bearing wings with bare stem veins.

Family	Genera	Hosts	Strike	Myiasis*
Calliphoridae	*Lucilia*	mammals	primary	Facultative (AU, CU, GI, NP, TR, UG)
	Calliphora	mammals	secondary	Facultative (AU, CU, GI, NP, TR, UG)
	Cochliomyia	mammals	primary, secondary	Facultative or obligate (TR)
	Chrysomya	mammals	primary, secondary	Facultative or obligate (TR)
	Cordylobia	mammals	primary	Obligate (CU, TR)

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

Five tribes are recognized in the subfamily Calliphorinae (namely, Bengaliini, Calliphorini, Luciliini, Melanodexiini, and Polleniini); with the tribe Calliphorini (bristly lower calypter, bare suprasquamal ridge) containing 18 genera (including *Calliphora*) and the tribe Luciliini (bare lower calypter, setate suprasquamal ridge) containing 5 genera (including *Lucilia*). The genus *Lucilia* (syn. *Acrophagella, Argoracrites, Bufolucilia, Caesariceps, Chaetophaenicia, Dasylucilia, Phaenicia*) contains over 260 species, with some classified in 4 subgenera but most remaining unassigned. Many species are known commonly as green bottle flies due to the metallic coppery-green thorax and abdomen of adults, although some species may be bronze to blue in colour. The genus *Calliphora* (syn. *Abonesia, Acronesia, Acrophaga, Steringomyia, Stobbeola*) contains almost 150 species with most classified in 12 subgenera, although 30 species remain unplaced. Many species appear as blue or brown bottle flies with a grey thorax and honey-coloured abdomen, but the colour variation of species ranges from black-grey through brown to blue-green. The larvae of several calliphorine species parasitize the dermal tissues of live mammalian hosts, causing fly-strike which is costly to livestock industries, in terms of lost production and expensive treatment and prevention. Many primary strike flies belong to the genus *Lucilia* (esp. *L. cuprina, L. sericata*) while many secondary or tertiary strike flies belong to the genera *Calliphora* (incl. *C. stygia, C. augur, C. albifrontalis, C. vicina*)

Calliphorid fly species	Hosts	Location	Clinical signs	Distribution
Tribe: *Luciliini* (bare lower calypter, setate suprasquamal ridge)				
L. cuprina (greenbottle fly, Australian sheep blow fly)	carrion, plus live sheep, other wild and domestic animals, human	skin	primary facultative myiasis (irritation, lesions, distress, anaemia, toxaemia, anorexia)	worldwide
L. sericata (European greenbottle fly)	sheep, other wild and domestic mammals, birds, lizards, human	skin	primary facultative myiasis (irritation, lesions, distress, anaemia, toxaemia, anorexia) (plus mechanical vectors for *Mycobacterium*)	worldwide
Tribe: Calliphorini (bristly lower calypter, bare suprasquamal ridge)				
C. albifrontalis (Western Australian brown blow fly)	carrion, plus live sheep, other wild and domestic animals	skin	secondary or tertiary facultative myiasis (lesions)	Australasia
C. augur (lesser brown blow fly, blue-bodied blow fly)	carrion, plus live sheep, other wild and domestic animals	skin	secondary or tertiary facultative myiasis (lesions)	Australasia
C. nociva (syn. *C. dubia*) (lesser brown blow fly)	carrion, plus live sheep, other wild and domestic animals	skin	secondary or tertiary facultative myiasis (lesions)	Australasia
C. stygia (syn. *C. laemica*) (large brown blow fly, eastern golden-haired blow fly)	carrion, plus live sheep, other wild and domestic animals	skin	secondary, sometimes primary, facultative myiasis (lesions)	Australasia
C. vicina (syn. *C. erythrocephala*) (bluebottle fly)	carrion, plus wild and domestic animals	skin	secondary facultative myiasis (lesions)	worldwide
C. vomitoria (bluebottle fly)	carrion, plus wild and domestic animals	skin	secondary facultative myiasis (lesions)	worldwide

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

***Lucilia* species**	**Subgenus**
L. adisoemartoi	Unassigned
L. aestuans	Unassigned
L. affinis	Unassigned
L. agilis	Unassigned
L. albofasciata	Unassigned
L. albofusca	Unassigned
L. amoena	Unassigned
L. ampullacea	Unassigned
L. andrewsi	Unassigned
L. angustifrons	Unassigned
L. angustifrontata	Unassigned
L. appendicifera	*Sinolucilia*
L. ardens	Unassigned
L. arrogans	Unassigned
L. arvensis	Unassigned
L. aurata	Unassigned
L. aureovultu	Unassigned
L. azurea	Unassigned
L. basalis	Unassigned
L. basifera	Unassigned
L. bazini	*Lucilia*
L. benigna	Unassigned
L. bicolor	Unassigned
L. bismarckensis	Unassigned

L. blanda	Unassigned
L. bufonivora	*Bufolucilia*
L. caerulea	Unassigned
L. caeruleiviridis	Unassigned
L. caerulescens	Unassigned
L. caesar	*Lucilia*
L. caesarina	Unassigned
L. caesarion	Unassigned
L. caesia	Unassigned
L. calidula	Unassigned
L. calviceps	Unassigned
L. campestris	Unassigned
L. carbunculus	Unassigned
L. chini	*Bufolucilia*
L. chrysella	Unassigned
L. chrysigastris	Unassigned
L. chrysis	Unassigned
L. cinctella	Unassigned
L. claviceps	Unassigned
L. cluvia	Unassigned
L. coccinea	Unassigned
L. coelestis	Unassigned
L. coeruleifrons	Unassigned
L. coeruleiviridis	Unassigned
L. cognata	Unassigned

L. consobrins	Unassigned
L. cornicina	Unassigned
L. corusca	Unassigned
L. cuprea	Unassigned
L. cuprina	Unassigned
L. cyanea	Unassigned
L. cyanella	Unassigned
L. cylindrica	Unassigned
L. deceptor	Unassigned
L. decora	Unassigned
L. delicatula	Unassigned
L. deses	Unassigned
L. diffusa	Unassigned
L. dimidiata	Unassigned
L. discolor	Unassigned
L. diversa	Unassigned
L. dives	Unassigned
L. docilis	Unassigned
L. dolosa	Unassigned
L. dorsalis	Unassigned
L. dulcis	Unassigned
L. elegans	Unassigned
L. elongata	Unassigned
L. erythraea	Unassigned
L. exilis	Unassigned
L. eximia	Unassigned
L. facialis	Unassigned
L. fastuosa	Unassigned
L. fausta	Unassigned
L. favilla	Unassigned
L. fayeae	Unassigned
L. fernandica	Unassigned
L. fervida	Unassigned
L. flagrans	Unassigned
L. flammea	Unassigned
L. flammula	Unassigned
L. flaviceps	Unassigned
L. flavidipennis	Unassigned
L. flavipalpis	Unassigned
L. floralis	Unassigned
L. foetida	Unassigned
L. fulgens	Unassigned
L. fulges	Unassigned
L. fulgida	Unassigned
L. fulvicornis	Unassigned
L. fulvifrons	Unassigned
L. fulvipes	Unassigned
L. fulvocothurnata	Unassigned
L. fumicosta	Unassigned
L. fuscanipennis	Unassigned
L. fuscipalpis	Unassigned
L. gemma	Unassigned
L. gemula	Unassigned
L. germana	Unassigned
L. glabrata	Unassigned
L. graphita	Unassigned
L. gratiosa	Unassigned
L. gressitti	Unassigned
L. hainanensis	*Lucilia*
L. hilaris	Unassigned
L. hirsutula	*Phaenicia*
L. hominivorax	Unassigned
L. hyacinthina	Unassigned
L. ibis	Unassigned
L. ignea	Unassigned
L. ignita	Unassigned
L. illustris	Unassigned
L. impatiens	Unassigned
L. incisuralis	Unassigned
L. inclyta	Unassigned
L. indica	Unassigned
L. infernalis	Unassigned
L. ingenua	Unassigned
L. insignis	Unassigned
L. insignita	Unassigned
L. inventrix	Unassigned
L. japuhybensis	Unassigned
L. juvenis	Unassigned
L. labialis	Unassigned
L. laetatoria	Unassigned
L. laevis	Unassigned
L. lenis	Unassigned
L. lepida	Unassigned
L. libera	Unassigned
L. ligurriens	Unassigned
L. limbata	Unassigned
L. limpidpennis	Unassigned
L. littoralis	Unassigned
L. locuples	Unassigned
L. lucigerens	Unassigned
L. luteicornis	Unassigned
L. magnicornis	Unassigned
L. magnifica	Unassigned
L. maialis	Unassigned
L. marginalis	Unassigned
L. marginata	Unassigned
L. meigenii	Unassigned
L. metallica	Unassigned
L. mexicana	Unassigned
L. micans	Unassigned
L. mirifica	Unassigned
L. modesta	Unassigned
L. modica	Unassigned
L. nigriceps	Unassigned
L. nigrifrons	Unassigned
L. nigrocoerulea	Unassigned
L. nitida	Unassigned
L. nitidula	Unassigned
L. notata	Unassigned
L. nuptialis	Unassigned
L. obscurella	Unassigned
L. obscuripalpis	Unassigned
L. ochricornis	Unassigned
L. ovatrix	Unassigned
L. pallescens	Unassigned
L. pallipes	Unassigned
L. papuensis	Unassigned
L. paraensis	Unassigned
L. parphyrina	Unassigned
L. pauperata	Unassigned

L. peronii	Unassigned
L. peruviana	Unassigned
L. pilosa	*Phaenicia*
L. pilosiventris	*Phaenicia*
L. pinguis	Unassigned
L. pionia	Unassigned
L. polita	Unassigned
L. porphyrina	Unassigned
L. praestans	Unassigned
L. prasina	Unassigned
L. pratensis	Unassigned
L. pretiosa	Unassigned
L. princeps	Unassigned
L. problematica	Unassigned
L. prompta	Unassigned
L. propinqua	Unassigned
L. pruinosa	Unassigned
L. pubescens	Unassigned
L. pulchella	Unassigned
L. pulverulenta	Unassigned
L. pumicea	Unassigned
L. purpurea	Unassigned
L. purpurescens	Unassigned
L. pyrochroa	Unassigned
L. pyrois	Unassigned
L. pyropus	Unassigned
L. quieta	Unassigned
L. rectinevris	Unassigned
L. regalis	*Phaenicia*
L. retroversa	Unassigned
L. rhodocera	Unassigned
L. rica	Unassigned
L. richardsi	*Phaenicia*
L. rognesi	Unassigned
L. rostrellum	Unassigned
L. rubicornis	Unassigned
L. rubrella	Unassigned
L. ruficeps	Unassigned
L. rufifacies	Unassigned
L. rutila	Unassigned
L. salazarae	Unassigned
L. sapphirea	Unassigned
L. scintilla	Unassigned
L. scutellaris	Unassigned
L. sericata	Unassigned
L. setosa	Unassigned
L. shansiensis	*Phaenicia*
L. shenyangensis	*Lucilia*
L. silvarum	Unassigned
L. sinensis	Unassigned
L. snyderi	Unassigned
L. socialis	Unassigned
L. solers	Unassigned
L. soror	Unassigned
L. spectabilis	Unassigned
L. spekei	Unassigned
L. spinicosta	Unassigned
L. stackelbergi	Unassigned
L. subtilis	Unassigned
L. sumptuosa	Unassigned
L. taiwanica	Unassigned
L. taiyanensis	*Phaenicia*
L. tenera	Unassigned
L. tepida	Unassigned
L. teres	Unassigned
L. terraenovae	Unassigned
L. thatuna	Unassigned
L. thoracica	Unassigned
L. timorensis	Unassigned
L. tomentosa	Unassigned
L. umbrosa	Unassigned
L. urens	Unassigned
L. vaga	Unassigned
L. valida	Unassigned
L. varipalpis	Unassigned
L. varipes	Unassigned
L. venusta	Unassigned
L. vernalis	Unassigned
L. viatrix	Unassigned
L. vicina	Unassigned
L. violacea	Unassigned
L. violacina	Unassigned
L. virgo	Unassigned
L. viridana	Unassigned
L. viridescens	Unassigned
L. viridifrons	Unassigned
L. viridis	Unassigned
L. viridula	Unassigned
L. viridulans	Unassigned
L. viva	Unassigned
L. vulgata	Unassigned
L. woodi	Unassigned

***Calliphora* species**	**Subgenus**
C. abina	*Acronesia*
C. alaskensis	*Acronesia*
C. albifrontalis	*Neocalliphora*
C. aldrichia	*Acronesia*
C. algira	Unassigned
C. alpina	*Acrophaga*
C. anana	*Acronesia*
C. antennatis	Unassigned
C. antipodes	Unassigned
C. antojuanaee	Unassigned
C. arta	*Eucalliphora*
C. aruspex	*Paracalliphora*
C. assimilis	Unassigned
C. atripalpis	*Calliphora*
C. augur	*Paracalliphora*
C. auriventris	Unassigned
C. australica	Unassigned

C. axata	*Paracalliphora*
C. bezzii	Unassigned
C. brunibarbis	Unassigned
C. bryani	*Oceanocalliphora*
C. cadaverum	Unassigned
C. calcedoniae	Unassigned
C. calliphoroides	*Triceratopyga*
C. canimicans	*Australocalliphora*
C. centralis	*Paracalliphora*
C. chinghaiensis	*Acrophaga*
C. clarki	Unassigned
C. clausa	Unassigned
C. clementei	Unassigned
C. collini	*Acronesia*
C. coloradensis	Unassigned
C. croceipalpis	Unassigned
C. dasyophthalma	Unassigned
C. deflexa	Unassigned
C. dichromata	*Paracalliphora*
C. dispar	Unassigned
C. dubia	*Paracalliphora*
C. echinosa	*Acronesia*
C. elliptica	Unassigned
C. erectiseta	*Calliphora*
C. espiritusanta	*Paracalliphora*
C. eudypti	Unassigned
C. fallax	*Paracalliphora*
C. flavicauda	Unassigned
C. floccosa	Unassigned
C. forresti	*Paracalliphora*
C. franzi	*Acrophaga*
C. fulviceps	*Paracalliphora*
C. fulvicoxa	*Paracalliphora*
C. fuscipennis	Unassigned
C. fuscofemorata	*Australocalliphora*
C. genarum	Unassigned
C. gilesi	*Paracalliphora*
C. grahami	*Aldrichina*
C. gressitti	*Paracalliphora*
C. grisescens	Unassigned
C. grunini	Unassigned
C. hasanuddini	*Paracalliphora*
C. hilli	*Paracalliphora*
C. himalayana	Unassigned
C. icela	Unassigned
C. insignis	Unassigned
C. io	Unassigned
C. irazuana	Unassigned
C. javanica	*Paracalliphora*
C. kanoi	*Paracalliphora*
C. kermadeca	*Paracalliphora*
C. lata	*Calliphora*
C. latifrons	Unassigned
C. leucosticta	*Paracalliphora*
C. lilaea	Unassigned
C. livida	Unassigned
C. loewi	*Calliphora*
C. lopesi	Unassigned
C. lordhowensis	*Australocalliphora*
C. macleayi	*Paracalliphora*

C. maestrica	Unassigned
C. majuscula	Unassigned
C. malayana	*Paracalliphora*
C. maritima	*Paracalliphora*
C. maryfullerae	Unassigned
C. melinda	Unassigned
C. metallica	Unassigned
C. minor	Unassigned
C. mogii	Unassigned
C. montana	*Acronesia*
C. morticia	Unassigned
C. mumfordi	*Paracalliphora*
C. neohortonaa	Unassigned
C. neozelandica	Unassigned
C. nigribarbis	*Calliphora*
C. nigrithorax	*Neocalliphora*
C. nociva	Unassigned
C. norfolka	*Paracalliphora*
C. nothocalliphoralis	Unassigned
C. noumea	Unassigned
C. ochracea	*Neocalliphora*
C. onesioidea	*Australocalliphora*
C. papua	Unassigned
C. papuensis	*Paracalliphora*
C. paradoxa	*Triceratopyga*
C. pattoni	*Calliphora*
C. perida	Unassigned
C. peruviana	Unassigned
C. phacoptera	Unassigned
C. plebeia	Unassigned
C. popoffana	*Acronesia*
C. porphyrina	*Paracalliphora*
C. praepes	Unassigned
C. prosternalis	Unassigned
C. psudovomitoria	Unassigned
C. pubescens	Unassigned
C. quadrimaculata	*Neocalliphora*
C. robusta	Unassigned
C. rohdendorfi	*Calliphora*
C. rostrata	Unassigned
C. ruficornis	Unassigned
C. rufipalpis	Unassigned
C. rufipes	Unassigned
C. salivaga	*Paracalliphora*
C. simulata	*Paracalliphora*
C. sinensis	*Calliphora*
C. splendens	*Calliphora*
C. splendida	Unassigned
C. stelviana	Unassigned
C. sternalis	Unassigned
C. stygia	*Neocalliphora*
C. stylifera	*Steringomyia*
C. subalpina	*Acrophaga*
C. tasmanensis	Unassigned
C. tasmaniae	Unassigned
C. terraenovae	Unassigned
C. testaceifacies	Unassigned
C. tianshanica	*Calliphora*
C. toxopeusi	*Papuocalliphora*
C. triseta	Unassigned

C. uralensis	Unassigned
C. varifrons	*Paracalliphora*
C. vicina	*Calliphora*
C. viridescens	Unassigned
C. viridiventris	Unassigned

C. vomitoria	*Calliphora*
C. xanthura	*Paracalliphora*
C. yezoana	Unassigned
C. zaidamensis	*Calliphora*

Parasite morphology: Blow flies form 4 different types of developmental stages: eggs, larvae (three instars), pupae and adults. Eggs appear as creamy-yellow ovoid-oblong bodies (~ 1 mm long) deposited in clusters. Larvae (commonly called maggots) have elongated cylindrical white-cream opaque bodies that grow through 3 developmental instars (L1-3) from 5-20 mm in length. They have reduced head capsules but possess distinctive cephalopharyngeal skeletons with a pair of anterior darkened rasping mouthhooks. They respire through spiracles, an anterior pair, each with 7-10 openings; and a posterior pair, each with one (*Lucilia*) or 2 (*Calliphora*) internal projections and 3 slanting oval slits in a sclerotized plate called a peritreme (in contrast, oestrid larvae have flat porous plates). The body has 12 conspicuous segments, often bearing segmental belts of small rounded projections (tubercles) giving it a 'screw-like' appearance (Oestroidea are distinguished from Muscoidea by larvae possessing rudimentary armature). Pupae are formed inside the exoskeleton of the last larval instar and appear as ellipsoidal creamy-brown cocoons (10-14 mm long) with barely visible transverse striations. The pupae are cyclorrhaphous with an anterior circular seam that forms an exit aperture. Calliphorid blow flies have robust bodies that are not dorsoventrally flattened, are distinctively coloured and adorned with characteristic patterns of setae (chaetotaxy). They are small-medium sized flies (measuring 8-14 mm in length) with metallic iridescent bodies (blue-black, violet-blue, green or bronze) and strong bristles (Oestroidea are distinguished from Muscoidea by the presence of bristles on the thoracic meron). *Lucilia* spp. are often referred to as green bottle flies due to their metallic coppery-green thorax and abdomen, although some species may be blue to bronze in colour. Different species are often distinguished by colour variations, e.g. *L. cuprina* and *L. sericata* are differentiated by the green and black colouration of the femurs on their front legs. *Calliphora* spp. are usually blue or brown bottle flies with a grey thorax and honey-coloured abdomen, but the colour variation of species ranges from black-grey through brown-copper to blue-green. Colour variation can also be used to distinguish species: e.g. *Ca. stygia* has a brownish chequered abdomen, *Ca. augur* has a bright blue longitudinal band on its abdomen and *Ca. dubia* has a darker blue band on the abdomen. Adults have 3 conspicuous body parts: a big round head; stout thorax; and pyriform abdomen. The head possesses both a ptilinal suture and facial lunule (like Muscoidea, but unlike other calyptrate flies), 2 large brown compound eyes (well separated in females and close together in males), and 2 well-developed short pendulous antennae, each composed of 3 dissimilar segments: a small basal scape; a club-like pedicel with a complete dorsal seam; and a large dorsal bristle (arista) that is bilaterally plumose (feathery) [oestroid and muscoid flies distinguished from other calyptrates by possessing antennae with aristae]. Calliphorids have well-developed sponging-sucking mouthparts to feed on liquids, but do not have piercing elements as they do not bite hosts and do not feed on blood. The ventral proboscis comprises a basal rostrum flanked by short palps, a cylindrical haustellum housing an anterior labrum, slender hypopharynx and sheath-like labium; and a terminal sponging labellum. Liquids ingested with the aid of pharyngeal muscles pass into a tubular oesophagus and proventriculus (with associated diverticula) and then to the digestive midgut, hindgut (with excretory Malpighian tubules), rectum and terminal anus. The thorax is covered by a scutum with a continuous mid-dorsal suture and a small post-scutellum. The scutum contains stout bristle-like setae, including a vertical row on the meron (lacking on muscoid flies), a row on the hypopleuron, and 3 postsutural dorsocentral pairs (in *Lucilia*). The mesothorax bears 2 narrow clear wings with wing membranes uncrowded and supported by 6 primary veins [costa (C), subcosta (Sc), radius (R), media (M), cubitus (Cu), and anal (A)]. Calliphorine flies have bare stem veins, M veins angled sharply upwards near the outer margin, and the discal medial cell widening gradually. The wings have prominent hind lobes (calypters or squamae), with *Calliphora* spp. having a bristly lower calypter and bare suprasquamal ridge, while *Lucilia* spp. have a bare lower calypter and a setate suprasquamal ridge. Like all Diptera, the hindwings have been greatly reduced to knobby halteres (used to stabilize flight), covered by the calypters (in all calyptrates). Oestroid and muscoid flies are further distinguished from other calyptrates by the presence of bulbous swellings (greater ampulla) below the wing base. The ventral thorax gives rise to 3 pairs of long thin legs, each composed of 5 segments (coxa, trochanter, femur, tibia, tarsus) and terminating in a pair of claws with pad-like pulvilli surrounding a central bristle (empodium). The pyriform abdomen usually has 5 conspicuous segments with lateral respiratory spiracles and terminalia specific for each gender (aedeagus and claspers for males, ovipositor for females). Males have 2 testes connected by vas deferens to a seminal vesicle (with lateral accessory glands) leading to a tubular ejaculatory duct and retractable copulatory aedeagus with claspers located near the genital pouch. Females have 2 ovaries joined by oviducts to a globular uterus (with associated spermatheca and accessory glands) opening to the vulva with a cylindrical telescoping ovipositor.

Site of infection: These blow flies are facultative parasites, particularly of sheep, and sometimes other domestic animals. Adult flies cause no direct harm but the larval stages emerging from eggs laid next to the skin invade host tissues, causing myiasis. Eggs are laid in batches of 50-250 on carrion or on moist wounds or the soiled wet fleece of live animals, causing body, breech, tail, poll (head) or pizzle strike depending on where emergent larvae invade cutaneous tissues. Some species may also invade body orifices, such as orbital, nasal, aural and anal passages, urogenital tracts and even the umbilical cords of newborns. Body strike is found commonly around the shoulders and along the back, and has been associated with bacterial dermatophilosis and pseudomonal fleece rot. In Merino sheep, breech and tail strike commonly occur due to the excessive wrinkled skin of the hindquarters that becomes fouled with faeces and urine.

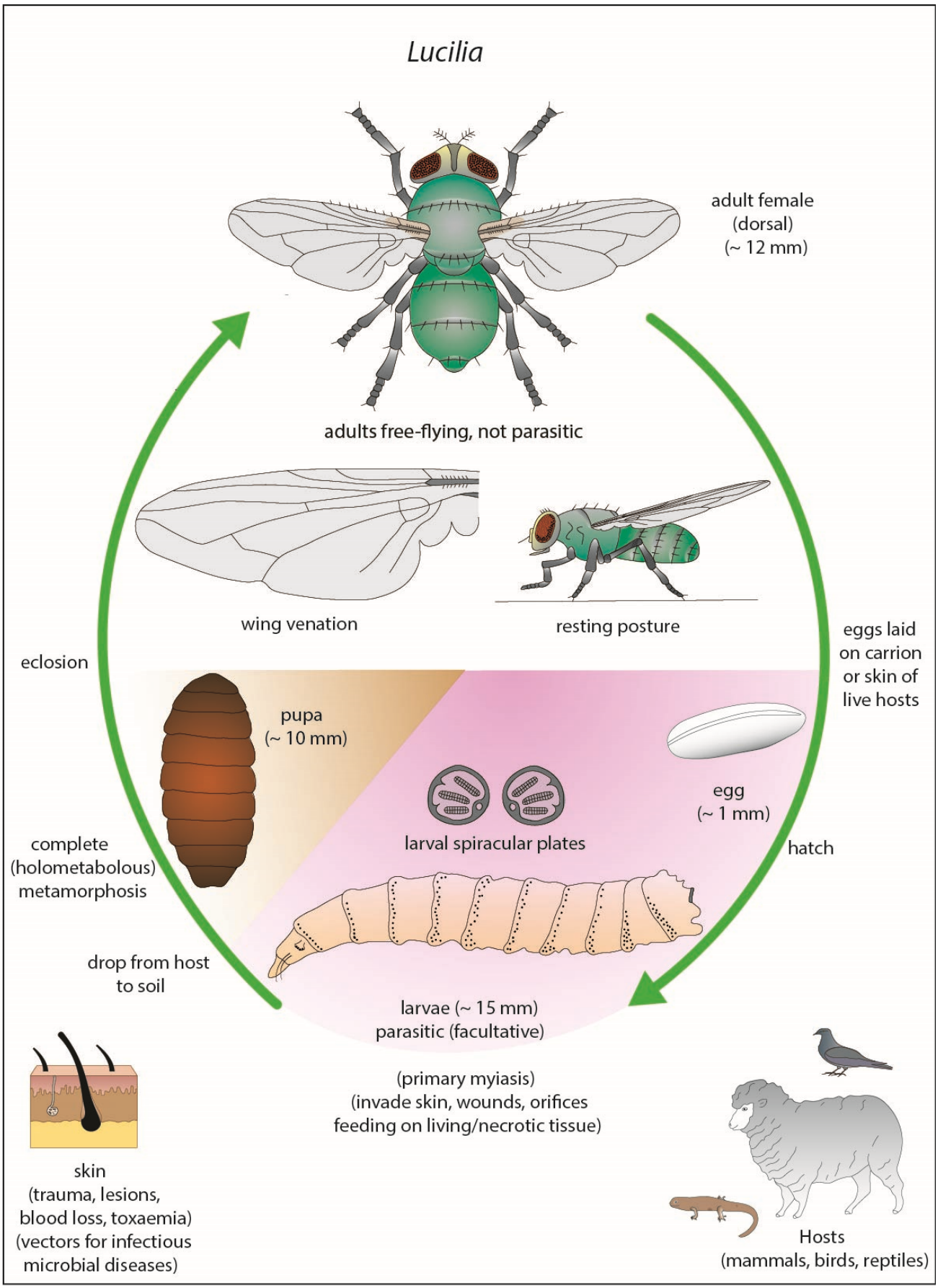
Pathogenesis: Some myiasis-causing fly species are obligate parasites and can only complete their development using a living host. The majority, however, are facultative parasites and can develop in both living and dead organic material. They comprise primary facultative species (such as *Lucilia* spp.), which can initiate myiasis but also live as saprophages in decaying organic matter or carcases, and secondary facultative species (such as *Calliphora* spp.), which live normally as saprophages and cannot initiate myiasis but can secondarily invade pre-existing infestations. Flies are attracted to soiled pelage (fur, hair, wool), pungent wounds and chronic nasopharyngeal and urogenital infections. Various odours appear to act as chemo-attractants, especially those associated with decomposing organic matter, but also including those produced by bacteria causing fleece rot or dermatophilosis on rain-soaked animals. Gravid females lay eggs on or around wounds (due to trauma, castration, tail-docking, de-horning, navels) and orifices (nostrils, eyes, mouth, ears, anus, vagina), areas that are moist and contain proteinaceous material for the emergent larvae. Fly strike may cause superficial or invasive tissue lesions, with considerable trauma, pain, stress, anaemia, and in severe cases, an acute and potentially fatal toxaemia due to ammonia excreted by the larvae. Facultative myiasis usually involves masses of maggots which can result in death of the host either directly (expanding invasive lesions) or indirectly (predisposing host to disease or predation). Obligate myiasis usually involve fewer larvae but they can be more invasive leading to deeper lesions. In both instances, larvae invade necrotic or living tissue causing traumatic cutaneous myiasis. Three larval instars develop over 4-6 days and they cause great suffering by feeding directly on host tissues. Maggots secrete proteolytic enzymes and tear at the tissues with strong oral hooks resulting in extensive lesions. Initially, larvae may feed superficially on skin and exudates or on necrotic tissue, but in crowded conditions they may feed on live healthy tissue in order to survive and continue their development. Larvae burrow into tissue headfirst, with their caudal spiracles exposed near the surface. Once replete, mature larvae drop from the host to the ground to form pupae. Single infestations by a few larvae may be well tolerated by the host, sometimes being covert producing few clinical signs and healing well without complications. Heavier or multiple infestations, however, can be extremely debilitating causing significant irritation and distress resulting in the host rapidly losing condition becoming anorexic, dull and depressed. Animals may chew, scratch or rub affected areas, resulting in cavernous painful lesions with progressive ulceration, necrosis and haemorrhage. Other primary, secondary and even tertiary blow flies are attracted to existing lesions resulting in prolonged infestations and expansive lesions. The amount of tissue damage is dependent on the cumulative duration of infestations and the numbers of maggots present. The severity of disease (myiasis) varies considerably depending on the sites of infestation and the extent of tissue invasion. Subcutaneous lesions may become so deep that they involve internal organs resulting in a wide range of clinical signs, including fever, anaemia, dyspnoea, renal dysfunction, cardiac signs and toxaemia, which may prove fatal around 2 weeks after initial infestation. Lesions are also predisposed to secondary bacterial infections, with toxaemia ranging from pyaemia to septicaemia.

Developmental cycle and mode of transmission: Blow flies have holometabolous developmental cycles involving the complete metamorphosis of vermiform larvae through a non-feeding pupa stage to form winged adults. Adult flies are free-flying and both sexes require water and carbohydrates for energy which they obtain from honeydew and juices from flowering plants. Most blow flies are anautogenous in that the females require a protein meal (usually from nectar or decaying organic matter) to complete oogenesis (egg maturation). Calliphorid flies are oviparous, females laying eggs after searching for suitable sites for oviposition; being attracted to carrion or moist body areas with putrefactive odours and protein exudates due to wounds, skin conditions (such as dermatitis) or pelage soiled with urine or faeces (especially dags on sheep). They lay batches of 50-250 eggs several times over 2-3 weeks, usually towards the end of the day to prevent their desiccation by prolonged exposure to sunlight. The eggs hatch after 6-24 hours although it may take longer in colder conditions. Emergent larvae begin to feed immediately on host tissue and they undergo two moults, one after 12-18 hours and another some 30-60 hours later. The first larval instars are highly susceptible to desiccation and are not capable of penetrating unbroken skin. The second and third instars are able to abrade skin with their oral hooks and they produce enzymes that break down the skin causing serous exudates. The larvae of some blow fly species also exhibit predatory behaviour and may feed on larvae of other species. After 3-6 days of feeding, replete larvae leave the host, drop to the ground and burrow into the topsoil or leaf litter where they shrink and harden to form non-feeding pupae. Pupation may be completed in 3-7 days or be delayed for several weeks by colder conditions. Adult blow flies are ready to mate several days after emergence and the fertilized females produce eggs over 2-3 weeks. The whole life-cycle (egg-to-egg) may be completed within 2-6 weeks, particularly warm humid regions. Blow fly populations exhibit seasonal fluctuations in their numbers and activity in response to prevailing climatic conditions and the availability of susceptible hosts. *L. cuprina* is more prevalent in warm-temperate and subtropical regions, while *L. sericata* is more prevalent in cool-temperate regions. Fly numbers typically increase during spring as temperature and humidity rise, but decrease during colder months. Pre-pupae can over-winter in the soil, resulting in their synchronized emergence and fly swarms in spring. Hot dry summers reduce fly numbers significantly unless sufficient rainfall occurs. Flystrike is worse in many agricultural areas when neonates (lambs, calves, foals) are abundant as they are more susceptible to infestation, particularly when wounded during castrating, branding, dehorning or shearing. The incidence of fly strike is also greater in animals with wet fleeces due to persistent rainfall. Infestations may spread within host populations and over time and space because female flies usually attack more than one host and larvae dropping from ambulatory hosts pupate in the soil over wide areas.

Differential diagnosis: Myiases are diagnosed on the basis of clinical signs and the detection and identification of larvae in lesions (sores, wounds, ulcers, furuncles). Physical examination of wounds can be aided by medical imaging technologies (such as ultrasound) to help differentiate lesions due to other aetiological agents (such as tungiasis, leishmaniasis, onchocerciasis, tropical ulcers, abscesses, pyogenic infections, adenopathy, cellulitis, furunculosis, and subcutaneous cysts). The larvae of most blow fly genera can be differentiated on the basis of their size, shape and appearance as well as the arrangement of their posterior spiracles. The spiracles of blow fly larvae have straight slits compared to sinuous slits in house fly larvae. The peritreme (outer perimeter) of

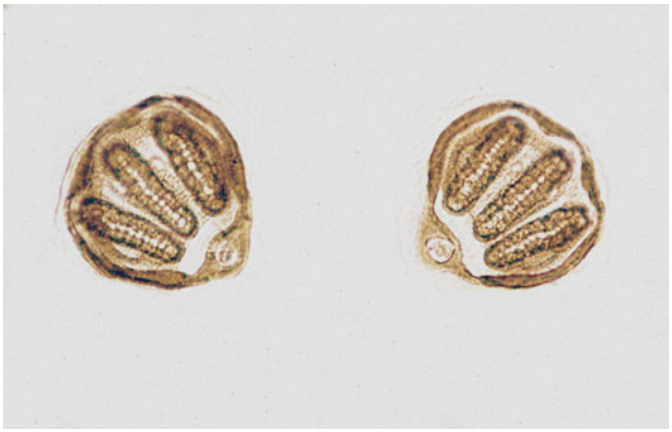
the spiracles is entire in primary strike flies and broken in secondary strike flies. It is thin in *Lucilia* spp. and thick in *Calliphora* spp. First stage larvae have one slit, second stage larvae have 2 slits and third stage larvae have 3 slits. The identification of individual species is often confounded by their similar morphology, so if required, live larvae extracted from the host may be maintained in the laboratory on meat or a synthetic medium to pupate and develop into an adult fly, which can then be identified by their distinctive morphological features. Several attempts have been made to develop less-demanding diagnostic tests using immunological assays for larval excretory-secretory (ES) products and other antigenic preparations, but they are confined to research laboratories. Molecular biological techniques have been used to genotypically characterize flies and larvae by polymerase chain reaction (PCR) amplification of specific gene sequences; including nuclear 16S ribosomal RNA, 18S ribosomal RNA, mitochondrial 12S DNA, cytochrome oxidase I and II, transfer RNA and NADH dehydrogenase.

Treatment and control: Four major approaches are used to control myiases: therapeutic intervention (wound treatment); chemoprophylaxis (periodic applications of insecticides); minimizing predisposing conditions (stock husbandry and management); and reducing fly populations (environmental management). Medical cases rely on prompt surgical interventions and debridement to extract larvae from wounds using tweezers, forceps or needles. Patients may require supportive anti-inflammatory, antiseptic and antibiotic therapy to counter symptoms and complications. Occlusive coverings of oily creams/dressings (petroleum jelly, lanolin, liquid paraffin, mineral oil, vegetable oil, beeswax, sometimes nail polish, adhesive tape, butter, chewing gum) have been used to suffocate larvae before their removal, and stringent antiseptics (hydrogen peroxide, chloroform) may entice larvae to exit wounds or body orifices (some early remedies involved using raw meat poultices). Standard veterinary practice for flystruck animals relies on the use of topical dressings or systemic insecticides that target larvae. Early formulations containing creosote, eucalyptus oil, paraffin, phenol and others were painted directly onto wounds mixed with resinous tar, while next generation formulations incorporated a wide range of insecticidal organochlorides and organophosphates into topical powders, pastes and sprays. However, significant problems were encountered with drug toxicity and flies developing resistance to organochlorides (especially DDT) and organophosphates (many are now banned as dips although some are still available as dressings). More recently, topical formulations of pyrethroids (permethrin, cypermethrin, deltamethrin) and spinosyns (spinosad) as well as systemic applications of salicylanilides (closantel) and macrocyclic lactones (notably ivermectin, doramectin) have been used to treat myiases with great effect. Domestic livestock are usually treated prophylactically to prevent infestations using organophosphorous and pyrethroid insecticides which persist in the pelage for up to 10 weeks. These formulations may be applied by whole body plunge dipping, jetting or shower sprays, taking care to maintain correct insecticide concentrations. In sheep, long greasy wool may act as a barrier to chemical treatment so many farmers often treat after shearing. Some insect growth regulators (cyromazine, dicyclanil) have given good protection as single pour-on applications but only when used in timely fashion before anticipated challenge. Ear tags impregnated with organophosphates or pyrethroids have been used with good effect, mainly on cattle. Spinosad and ivermectin can also be given as jetting treatments, the latter also being available as an injectable or in the form of an intra-ruminal controlled-release bolus. Domestic animals should be regularly inspected during fly season, and infested individuals should be isolated and treated. Various livestock management procedures have been developed to prevent strike, such as dagging (removing faecally-soiled wool), crutching (shearing wool around breech), tail docking (amputation) and mulesing (removing hindquarter skin folds). Infections by gastrointestinal helminths should also be controlled to prevent diarrhoeal wetting of perineal wool. Certain breeds of sheep are more susceptible to strike because the wool and skin are too easily wetted with urine or remain wet after rain. Breeding plain-bodied sheep with fewer wrinkles and barer breech areas reduces the problem of fly strike. Many blow fly species multiply in carrion so every effort should be made to remove and destroy carcases in the field. Shallow burying may not be effective as some larvae have been found to burrow through metres of loose soil. Several studies have used carcases treated with insecticides and chemo-attractants as baited traps for fly control, but large-scale control would pose many logistic problems. Good results have been obtained in controlling other insect populations by releasing irradiated sterile males bred in the laboratory to compete for wild-type mates, but the best results were obtained in small confined areas with low population densities. More recently, a good case has been made for developing a vaccine for flystrike. Acquired resistance has been well documented in sheep and studies on passive immunity have shown that antibodies from previously infested sheep have conferred some protection to recipient animals by reducing larval growth. Several studies have subsequently reported larval growth inhibition in animals vaccinated with antigenic extracts from the larval peritrophic membrane of *L. cuprina,* but studies are on-going. Lastly, mention must be made of two alternate applications involving blow fly larvae. Several species (including *L. sericata*) have been used for ‘maggot debridgement (debridement) therapy’ to treat humans with non-healing wounds (pressure ulcers, venous stasis ulcers, diabetic foot wounds, postsurgical wounds) whereby sterile laboratory-reared maggots were used to clean wounds by preferentially feeding on dead necrotic tissue. In forensic entomology, calliphorid flies have also been used to provide information about the time of host death (post-mortem interval) based on the kinetics and dynamics of their larval activity.

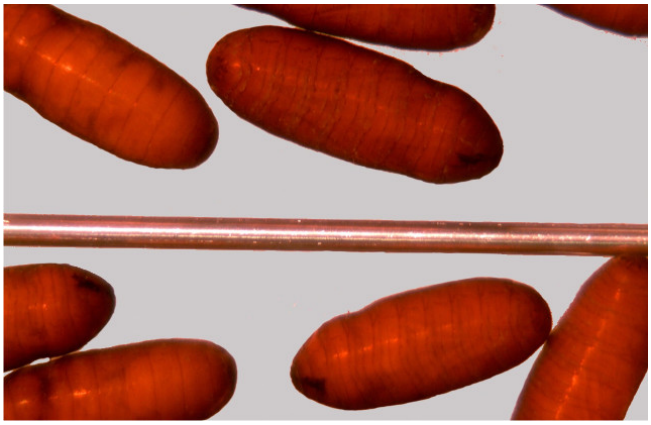

Lucilia
adult female
(dorsal)
(~ 12 mm)
adults free-flying, not parasitic
wing venation
resting posture
eggs laid
on carrion
or skin of
live hosts
egg
(~ 1 mm)
hatch
larval spiracular plates
larvae (~ 15 mm)
parasitic (facultative)
(primary myiasis)
(invade skin, wounds, orifices
feeding on living/necrotic tissue)
drop from host
to soil
pupa
(~ 10 mm)
complete
(holometabolous)
metamorphosis
eclosion
skin
(trauma, lesions,
blood loss, toxaemia)
(vectors for infectious
microbial diseases)
Hosts
(mammals, birds, reptiles)

Lucilia adult

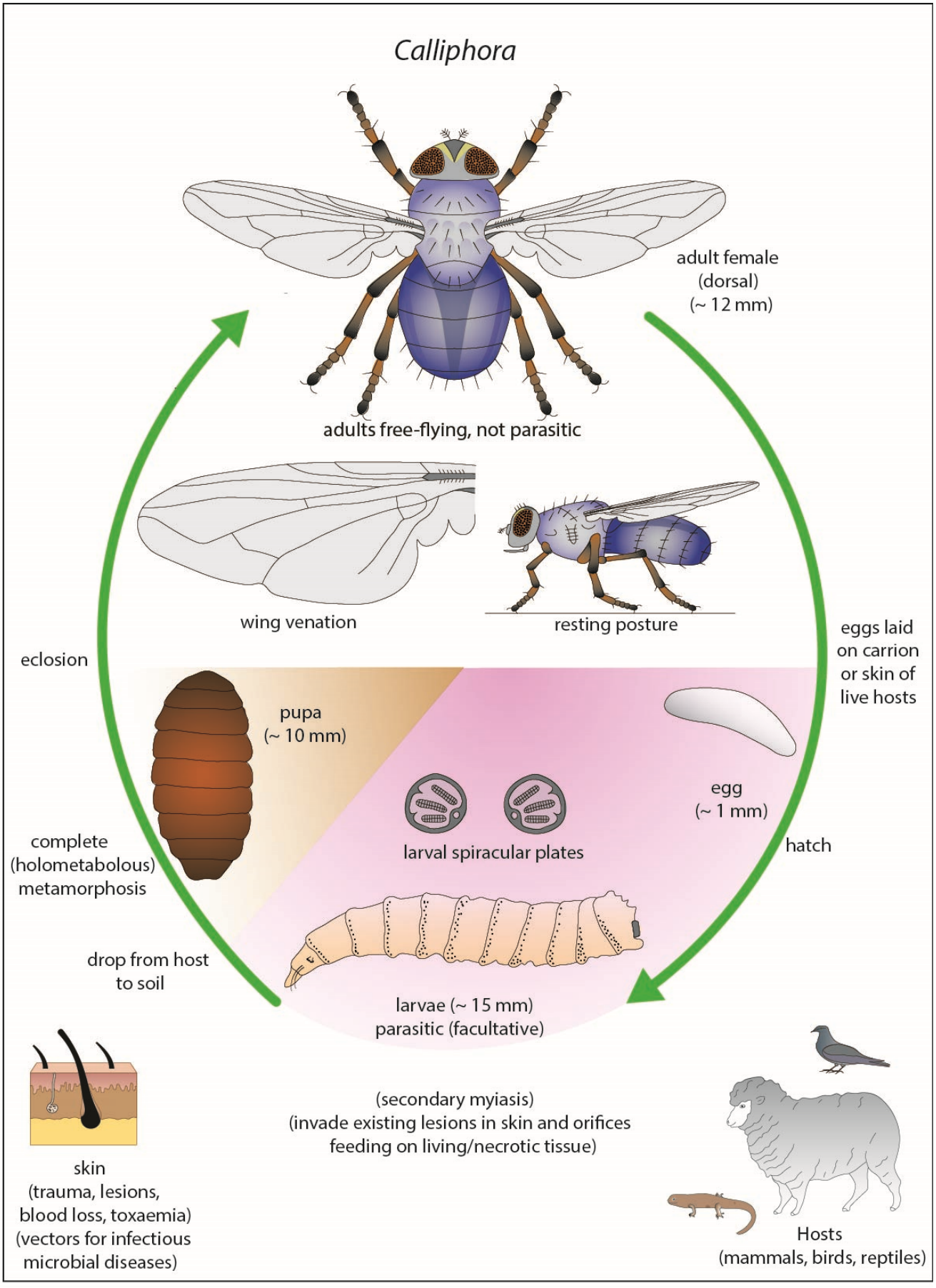
Lucilia larvae



Lucilia larval spiracles



Lucilia pupae


Calliphora
adult female
(dorsal)
(~ 12 mm)
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(trauma, lesions,
blood loss, toxaemia)
(vectors for infectious
microbial diseases)
Hosts
(mammals, birds, reptiles)

Calliphora adult

Calliphora eggs

Calliphora larvae

Calliphora larval spiracles