

2.3. Classification of insect orders viz., Lepidoptera and Diptera with economically important families

01. LEPIDOPTERA

Introduction

The Order Lepidoptera comprises over 160,000 species of butterflies and moths, with most of these being moths. The Lepidoptera are probably the most widely studied order of invertebrates, and have been for more than 400 years. More books have been written about them than on any other group of invertebrates. Indeed, the long history of their study by Lepidopterists has itself been the subject of a few books, and is a fascinating study on its own! Scientifically, there is no real distinction between butterflies and moths. However, in general, butterflies are day flying, whilst moths fly mainly at night. Butterflies are usually slimmer bodied, and have thin antennae with distinct clubs at the end. Moths have antennae of various designs, from thin and tapering to wide and 'feathery'. Feathery antennae are found in male moths, and help them to sniff out females! Due to their often bright colours and association with warm sunny days, butterflies have tended to catch the popular imagination over the centuries, more than any other insects. They can even be found adorning some ancient Egyptian tombs. Moths are not always thought of so highly, no doubt due to their nocturnal habits and duller colours. However, many moths are brightly coloured and fly during the day. On the other hand, some butterflies are active at twilight, and some are no more brightly coloured than many moths. Even the tiniest moths can look spectacularly beautiful when viewed closely.

Moths are often arbitrarily split into two groups - the larger moths, or *macrolepidoptera* (macros) and the smaller moths, or *microlepidoptera* (micros). While the micros tend to be more primitive in evolutionary terms, this is not always the case; and, some micros are in fact larger than some of the macros! So, like the division between moths and butterflies, this distinction is arbitrary too, and has no scientific basis. The one advantage these subdivisions do have is that people can study and get to know the Lepidoptera in stages.

Main characters of Order

1. The scientific name of the order, Lepidoptera, is derived from one of their main characteristics, namely their having wings covered in tiny scales (from the Greek lepidos = scale and pteron = wing). Indeed, it is these coloured scales which give them their patterns. These scales are specially modified flattened hairs.
2. The Lepidoptera undergo complete metamorphosis, i.e. ova (egg), from which emerge larvae (caterpillars), which become the quiescent pupae (chrysalis) from which emerge the imago (winged adult). This lifecycle can take anywhere between a few weeks to more than a year, depending upon the species.

3. Lepidoptera are 'typical' insects, in that they have 4 wings, 6 legs, 2 antennae and a body divided into 3 sections - a head, thorax and abdomen. The leg and wings are attached to the thorax. In a few species of moths, the females have evolved to become wingless.
4. Most butterflies and moths feed through a specialised tube formed by some of the mouthparts, known as a proboscis. Nectar is the usual food for adults.
5. Sense organs on the feet can taste certain food substances with a greater sensitivity than the human tongue.
6. The wings consist of an upper and lower membrane supported by a system of hollow veins.
7. Most Lepidoptera larvae feed exclusively on plant matter, but a few are carnivorous for at least part of their life. Some species feed on a wide variety of plants, whilst others are willing to accept only one or two.
8. The larvae moult several times, usually 4, 5 or 6 depending upon the species.
9. The final moult reveals the pupa, which can be attached to part of the foodplant or other nearby item, unattached amongst debris such as leaf litter, or in a silk lined chamber underground.
10. Survival strategies of butterflies and their earlier stages include camouflage, toxic defence such as being distasteful/harmful or mimicking species that are distasteful/harmful.
11. Some species are quite small, having a wingspan of only a few millimetres, whilst others are giants among the insect world, being 30cm across.

Superfamily: Micropterigoidea

Family: Micropterygidae (Mandibulate Moths)

Small moths, with wingspan usually less than 10 mm. Head with rough vestiture of scales; head capsule only moderately extending above upper margin of compound eyes: dorsally with two prominent ocelli; antennae moniliform; labrum large, movable and extensively desclerotized; mandibles large and functional, with well developed articulation on head capsule; maxillae with long, folded, 5-segmented palps, erect and sclerotized lacinia, and with galear not long and forming a proboscis; labial palps short and 2-segmented. Wings narrow and lanceolate, held roof-like over body when at rest; upper surface usually with iridescent scale patches; fore wing with Sc forked near middle and M4 absent; hind wings with three or four branches to Rs, and without a produced jugal lobe. Middle tibia without spurs, but with apical tuft of setae; hind tibia with four apical spurs. Adult moths, which emerge in the spring, are usually diurnal, but nocturnal activity is reported in some species. Adults are attracted to flowers and feed on pollen, which they crush with the mandibles. Larvae feed on moss and liverworts, and can occur in soil. They pupate inside a silk cocoon. Worldwide there are 121 species in eight genera, but there are many new species undescribed.

Superfamily: Tineoidea**Family: Tineidae (Cloth moth)**

Very small to medium-sized moths, usually dull and brownish, with wingspan 8 to 14 mm. Head with erect piliform scales, and without visible ocelli; antennae filiform with scape smooth-scaled in most genera; maxillary palp strongly developed, 5-segmented and folded; labial palps 3-segmented, with stiff lateral bristles; proboscis very short or even absent, and never strongly sclerotized; galea short, disassociated, not strongly sclerotized, and if rolled, rolled haphazardly. Wings typically moderately broad, and generally subovate in shape; scales of fore wing often in rough or raised patches, and some taxa with sex scales; typically full complement of free veins in fore wing, with Rs4 terminating on costa; adults resting with wings held roof-like over body, and with body parallel to substrate. Hind tibia with erect and elongate scales on upper surface; adults moving with characteristic scuttling run. Practically all tineid larvae are fungivorous, with a substantial part of their food being fungal tissue. Thus many larvae are found in rotten wood, or in plant or animal matter. Some detritophagous tineids are commensals in the nests of social insects, or are associated with human dwellings, where they can be pests of stored food products, furnishings or fabrics, feeding on wool, fur and feathers. Many tineid larvae, including the household pests, build portable cases from which they feed. Prior to pupation, the larvae move to a pupation site, usually well away from the food source. Worldwide there are about 3000 species in 320 genera. Both of the introduced clothes moths, namely the casemaking clothes moth (*Tinea pellionella* (L.)) and the webbing clothes moth (*Tineola bisselliella* Hummel), can be household pests. The commonest species in homes is the Indian meal moth *Plodia interpunctella* (Hüber), a pest of stored products.

Family: Psychidae (Bagworm moths)

Usually small to medium sized moths, with wingspan 8 to 25 mm. Head with moderately long, slender to piliform scales directed forward; ocelli usually absent; proboscis, maxillary and labial palps reduced or absent. Males fully winged; females winged, brachypterous, apterous or vermiform, with all body appendages vestigial or absent. Larvae are lichen feeders, and form portable bags, a case made of pieces of twig, leaves or other material, which they carry around with them as they feed. Bags or cases are usually open at both ends, the top opening being used for feeding, and the lower for waste discharge. Pupation takes place in the larval bags or cases. Males leave the bag on emergence, departing from the lower end. Females spend their whole life in the bag or case, and if they leave, do so after egg laying. Males, if present, fertilize the female in the bag, through one end of the case. Worldwide there are nearly 1000 known species eg., *Apterona helicoidella* (Vallot), *Dahlica lichenella* (L.), *D. triquetrella* (Hüber) and *Hyaloscotes pithopoera* (Dyer)

Superfamily: Yponomeutoidea**Family: Plutellidae (Diamondback Moths)**

Plutellid moths have wingspans of about 10 to 50 mm (under 30 mm our fauna); the wings are usually narrow and often oddly-shaped with the hind wing frequently as wide as the fore wing. The fore wings are often brightly patterned (the

hind margin of the fore wing frequently shows a pale stripe) but normally are not metallic. The head bears ocelli and the antennae are thread-like with a basal pecten. An unscaled proboscis is present. Veins Rs and M1 in the hind wing are separate; M3 and CuA1 are also separate. In the fore wing R4 and R5 are not stalked. The tibial spurs are 0-2-4 and an epiphysis is present. Larvae are solitary leaf-rollers or live in loose webs and skeletonize leaves; most pupate in a characteristic, open-mesh cocoon. Adult moths hold their antennae forward when at rest. *Plutella*, a cosmopolitan genus of over 40 species feeds largely on plants of the mustard family; the Diamondback Moth, *P. xylostella* (Linnaeus), is a world-wide pest and one of the few micro-moths that migrates long distances. The family Plutellidae is world wide but small, with fewer than 100 known species eg., *Plutella xylostella* (Linnaeus), a pest of cabbage. It eats a wide range of crucifers, including garden ornamentals such as alyssum, stocks and wallflowers.

Superfamily: Gelechioidea

Family: Gelechiidae (Gelechiid Moths; Twirler Moths)

Usually brown or grey with wingspans of 6 to 25 mm. The fore wing is often narrowly rounded or pointed at the apex and the hind wing often has the tip prolonged and the margin behind concave. The head is smooth scaled; the labial palps are frequently long and upcurved. Ocelli are often present. The antennae are usually thread-like and there is usually no pecten. Vein CuP is absent in the fore wing. The hind wing has R1 and Sc united from the wing base or with R1 running into Sc beyond the base. The discal cell in the hind wing is closed perpendicular to the long axis of the wing or at 45° toward base of wing from M2. Gelechiid larvae roll or mine leaves, bore in stems and roots, produce galls or feed on seed heads or dried seeds in over 80 plant families. Some are economically important including *Sitotroga cerealella* (Olivier), the Angoumis Grain Moth, a major cosmopolitan pest of stored grain. Its eggs are used as hosts for rearing *Trichogramma* wasps, microscopic egg parasites, for the biological control of various pests. *Pectinophora gossypiella* (Saunders), the Pink Bollworm, attacks cotton flowers and bolls; it is considered one of the most economically damaging insects in the world. The family Gelechiidae is cosmopolitan and diverse, with 507 genera and 4530 described species.

Superfamily: Cossioidea

Family: Cossidae (Carpenter Moths, Goat Moths)

Members of the Cossidae are small to large heavy bodied moths, with wingspans ranging from about 1 to 24 cm. (usually less than 10 cm in North American species). Usually, the fore wings are long and narrow and the abdomen extends beyond the hind wing. The antennae are usually bipectinate in males, thread-like in females. There is no proboscis. The fore wing has an accessory cell near the apex of the discal cell, some branches of vein R usually stalked and 1A+2A is present and CuP is present or absent. In the hind wing the frenulum is a single bristle in males, 2 to 30 bristles in females; M is usually forked in the discal cell, CuP is present, sometimes absent basally and there are two anal veins. The larva is stout and pale, with a small head and a large sclerotized shield on top of the prothorax.

The pupae are elongate, well sclerotized and often have a spine on the head. Cossid larvae are woodborers or, in a few cases, tunnel in the soil and feed externally on roots. Many are smelly, a characteristic that has given the family one of its English names -- goat moths. The larvae of some species may take up to four years to mature. Many species can seriously damage trees. The Carpenter worm, *Prionoxystus robiniae* (Peck), a common and widespread Nearctic species, produces extensive galleries that weaken oaks, locusts, maples, elms and other trees. The larvae overwinter in the tunnels, which are about 1.5 cm in diameter and pupate in associated chambers; the cocoons are mixtures of silk and wood chips. The pupa is extruded from the tunnel when the adult emerges. Except for a few Asian species, adults are nocturnal. Females usually lay eggs in bark crevices using an extendible ovipositor but, in some groups, surface egg masses are produced. The family Cossidae contains about described 670 species arranged in about 113 genera throughout the world.

Superfamily: Tortricoidea

Family: Tortricidae (Leafroller Moths)

Tortricids are small to medium-sized moths; wingspans range from about 7 to 35 mm, rarely to 60 mm. The fore wings are broad and usually square-tipped, giving the adult a characteristic bell- or shield-shape when the wings are folded tent-like at rest. The moths are usually cryptically coloured – tan, brown or grey and striped, spotted or marbled – but many have shining metallic markings. On the head, scales are upwardly directed on the lower half of the frons and there is often a strong tuft of scales protruding between the antennae. Ocelli are almost always present. The antennae are thread-like, often slightly saw-toothed, and often with sensory hairs. The proboscis is well developed and is scaleless near the base. The labial palps are prominent, upturned or drooping; maxillary palps small. An epiphysis is present at the middle of the fore tibia; the tibial spur formula is 0-2-4. The mid tibia typically has modified scales that give the surface a spiny appearance. Females have large flat ovipositor lobes. Tortricid eggs are strongly flattened and scale-like; they are deposited singly, in small clusters or in large masses and sometimes they are covered, or fenced in, with debris or scales. Larvae use a vast array of plant families. Many species are leafrollers, but larvae of many species have other habits; there are leaf-tiers, feeders in buds, flowers, shoots and seeds and borers in plant parts. Leaf-rolling larvae often pupate in a silk-tied shelter on the food plant; many boring larvae pupate in the ground. Most adults are nocturnal, but there are several brightly coloured day-flying groups. The Tortricidae contains many agricultural and forestry pests. The most notorious are the Spruce Budworm, *Choristoneura fumiferana* (Clemens), which has devastated conifer forests in northeastern North America and the Codling Moth, *Cydia pomonella* (Linnaeus), a serious pest of apples. Its close relative, *C. deshaisiana* (Lucas) (Mexican Jumping Bean Moth) is a novelty; the seed of a *Sebastiania* plant (Euphorbiaceae) dances as the larva wriggles within. *Cydia pomonella* (Linnaeus) is the infamous Codling Moth, introduced from Europe to North America and first reported in British Columbia in 1900. The moth larva damages apples by feeding in the core and tunneling out when full grown; it also attacks pears, walnuts and other fruits. Much work on the control of this serious

pest, especially by the sterile male technique, has been undertaken in the Okanagan Valley since the 1960s.

Superfamily: Pyraloidea

Family: Pyralidae (Pyralid Moths, Snout Moths)

Pyralids are mostly small to medium-sized moths, with wingspans ranging from about 10 to 55 mm. On the head, the scaling of the frons is usually smooth; the eyes are normally large, globular and lack obvious hairs. The antennae are threadlike or sometimes pectinate or bipectinate. The proboscis is present and scaled at base, or can be reduced or even absent. Labial palps are 3-segmented, angled upward or upturned in front of face; maxillary palps are smaller, often minute or absent. Vein R5 of the fore wing is stalked or fused with R3+4. In the hind wing Sc+R1 is very close to, or joined to, Rs for some distance beyond the discal cell. The fore tibia has an epiphysis; the tibial spurs normally are 0-2-4. Tympanal organs are not on the thorax but are paired on the ventral part of the abdomen base, facing forward towards the thorax. The tympanal case is only narrowly open anteriorly. About two-thirds of described pyralids are in the subfamily Phycitinae; they are mostly leaf rollers, but many bore in buds, shoots, stems, cones, fruits, galls or under bark. For example, genus, *Dioryctria* often eat the cones, as well as the foliage, of evergreen trees. Larvae of some Galleriinae feed on dry plant material; the Rice Moth, *Corcyra cephalonica* Stainton is a widespread pest. A few species such as *Galleria mellonella* (Linnaeus), the Greater Wax Moth, feed on combs of hymenopteran nests and can destroy Honey Bee hives. *Tirathba* species are pests of coconut and other palms. There are about 6200 described species.

Superfamily: Hesperioidea

Family: HesperIIDae (Skippers)

Skippers get their English name from their characteristic, rapid and darting flight. They are small to medium-sized butterflies, the largest British Columbia specimens having wingspans less than 5 cm. Most have dull brown, grey or orange colours, and with their stout muscular bodies and short wings, resemble moths. The head is broad; the clubbed antennae arise far apart and the club is usually narrowed and hooked at the tip. All three pairs of legs are used for walking and the fore wing has 12 veins unbranched from the discal cell or the wing base to the wing margin. The larvae are usually smooth and unornamented; the head is large and separated from the rest of the body by a narrow, neck-like prothorax. Hesperiid larvae live in silk-lined nests on the food plants, which they construct by cutting and folding leaves or by using several leaves bound together. Some species build a cover of leaf bits or debris and carry this around while they feed. A few bore in plant tissue. Food plants include a wide range of angiosperms, but the diverse and widespread subfamily Hesperiidinae (and some others) feeds exclusively on monocots such as grasses, lilies, orchids and palms. A few species, especially in the tropics, may be economically important – some eat the leaves of rice, sugarcane, palms and bananas. When considered the sole family in the superfamily Hesperioidea, the Hesperiidae contains about 3500 species in over 500 genera. The most distinctive

species, *Epargyreus clarus* (Cramer) (Silver-spotted Skipper) has a large silvery spot on the underside of the hind wing.

Superfamily: Papilionoidea (Butterflies)

Family: Papilionidae (Swallowtails)

Butterflies in the Family Papilionidae have hairless eyes, short antennae and three fully developed pairs of legs. The fore wing has 11 or 12 veins; veins 1A and 2A are separate. The species range from about 40 to about 105 mm in wingspan with yellow or white with black markings and all our members of the subfamily Papilioninae (swallowtails) have tails on the hind wings while those in the subfamily Parnassiinae (apollos) do not (these characteristics do not hold for the world fauna of the family). Parts of the wings of apollo, especially the outer borders, lack scales; this condition is usually more striking in females than males. The larvae usually lack spines and have a Y-shaped, eversible gland (osmaterium) on the top of the thorax that, in most species, produces defensive chemicals to deter predators. Young swallowtail larvae look like bird droppings. The pupae in the Papilioninae have a silk girdle that helps hold them to the plant on which they have pupated. Swallow tail food plants are varied – a few examples include umbellifers (*Papilio zelicaon*, *P. indra*), chokecherry (*P. multicaudatus*), willows, poplars, alder and birch (*P. canadensis*, *P. rutulus*), *Ceanothus* (*P. eurymedon*) and *Artemisia* (*P. bairdii*, *P. machaon*). Swallow tails are strong fliers and males of some species often search out mates by hilltopping, a mating strategy where individuals fly uphill until they meet in concentrations at the height of land. The Family Papilionidae contains about 600 species in 26 genera worldwide.

Family: Pieridae (Whites, Marbles and Sulphurs)

Pierids are mostly medium-sized butterflies, generally white, yellow, orange or greenish, marked in black and frequently other colours. Males and females are often strikingly different in appearance. For example, in sulphurs, males usually have a solid black wing border, while that of females often has pale markings, is reduced or is even absent. Different generations of a species in a single year may show different markings. There are three functional pairs of legs and the two claws on the end of each leg are divided in two. The larvae are cylindrical, striped and covered in fine, short hair. The introduced European *Pieris rapae* (Linnaeus) (Cabbage White) now occurs all over the world where cabbage, broccoli, mustards and other crucifers are cultivated. *Colias eurytheme* Boisduval (Orange Sulphur) can be a pest of alfalfa, at least in warm climates where populations are large. The larvae of sulphurs overwinter; whites spend the winter in the pupal stage. The family Pieridae contains about 1000 named species in 75 genera

Family: Nymphalidae (Brush-footed Butterflies)

They are medium-sized (40 to 70 mm wingspan) and many are orange or brown with dark markings -- but size and colour vary greatly. Both sexes have their forelegs reduced in length and covered in long brush-like hairs, thus the English name of the group. These legs are useless for walking or perching but are used as sense organs. The face is broad, the eyes are not indented adjacent to the antennae

and the latter usually have prominent clubs. Caterpillars commonly have branched spines; the hind end of the larvae of the Satyrinae is forked. The pupae are often strongly angled, bear thorn-like projections and lack a silk girdle. Many nymphalids are strong fliers and some species are migratory and are among the most cosmopolitan of insects (*Vanessa*, *Danaus*). The Nymphalidae is perhaps the largest family of butterflies with about 6000 species in 350 genera in all areas supporting butterflies.

Superfamily: Geometroidea

Family: Geometridae (Geometer Moths, Loopers)

Geometer moths are small to large (about 10 to 50 mm wingspan to over 100 mm, typically slender bodied with broad, delicate wings. In our fauna, colours are usually subdued, with browns, greys, whites and rusts predominating; some are green, yellow, or black and white. Frequently delicate lines or bands cross both wings from front to back. In some species the females are short-winged or wingless; wing loss is more common in the Geometridae than in any other lepidopteran family. The head is densely scaled and the antennae are thread-like, serrate or bipectinate. Ocelli are normally absent. The proboscis is usually present (sometimes reduced or absent) and lacks basal scaling. The fore tibia bears an epiphysis; the typical tibial spur count is 0-2-4. In the hind wing, vein SC is often bent strongly near the base and may lie close to, or fuse with, Rs for part of its length. Vein M2 usually arises midway between M1 and M3, or nearer M1, or may be absent. A pair of structurally unique tympanal organs occur at the base of the abdomen; these open ventrolaterally. Most larvae have lost the front three of the usual five pairs of prolegs, but some species have retained more than two (with some reduced). Adult geometrids are mostly nocturnal and many are attracted to lights; when resting they typically hold the cryptically coloured wings outspread, but some fold the wings tightly over the abdomen. Some species are diurnal and some of these are brightly coloured. The loss of prolegs results in the looping habit of the moving larva; the name "Geometridae" is derived from this "earth measuring" motion. Other names -- measuringworms, inchworms, spanworms, loopers -- refer to this distinctive movement. Characteristically, many caterpillars are beautifully camouflaged and, when disturbed, may stand erect on the prolegs, strikingly resembling a little twig. The larvae usually are externally feeding defoliators, although some attack fruits, dead leaves and stored products; a few are carnivorous. Many are serious pests, especially of fruit-bearing shrubs and trees and ornamental and forest trees. Food preferences of some genera are wide-ranging. For example, although the larvae of most species in the large cosmopolitan genus *Eupethecia* conceal themselves in buds and flowers or bore in cones, in Hawaii they ambush and devour small insects and spiders. As larvae *Scopula* species feed mostly on herbaceous plants, but adults of some species in Southeast Asia imbibe blood from wounds in mammals, or sip sweat and even tears. The family Geometridae is huge, containing 21,000 species globally; in the Lepidoptera it is second in size only to the Noctuidae. Many species of the Geometridae are forest defoliators while the most damage is done by *Lambdina fiscellaria* (Guenée), whose larvae eat a wide range of evergreen and deciduous trees.

Superfamily: Lasiocampoidea

Family: Lasiocampidae (Tent Caterpillar Moths, Lappet Moths)

Lasiocampids are medium-sized to very large, stout-bodied, hairy moths. with wingspans ranging from about 25 to 35 mm and are predominantly brown, yellow or grey. The fore wing has vein R distinctly close to Sc towards the wingtip and vein CuA2 arises in the basal half of the discal cell. There is no frenulum to link front and hind wings in flight; instead, the front of the hind wing base is expanded and humeral veins are present. The mouthparts are non-functional, the eyes are often haired and the antennae are somewhat feathery, especially in males. Tent caterpillar larvae (*Malacosoma*) are hairy and often colourful, with stripes and spots of white, blue, orange and other colours. Lappet moth larvae (*Tolype*, *Phyllodesma*) are softly hairy have a small lobe or lappet on either side of each segment. Larvae of the Lasiocampidae feed mostly on deciduous trees and shrubs. Lappet moths seldom reach pest status but the tent caterpillars often cause severe defoliation during cyclical outbreaks. They live in colonies in spring and most kinds, including a common species, *Malacosoma californicum* (Packard) (Western Tent Caterpillar), construct silken tents in branch forks and tips for shelter. They also deposit trails of silk as they move from the tents to feeding sites on the foliage. The widespread *M. disstria* Hübner (Forest Tent caterpillar) does not construct nests, but lives in large, sometimes immense, aggregations linked by silk trails. Mature larvae wander and, when shelter is found, pupate in cocoons made of silk and hair. The adults produce eggs banded around twigs and covered with hardened foam; the moths overwinter as unhatched larvae. Adults rest in a distinctive posture: the fore wings are held tent-like and often much of the anterior part of the hind wing is uncovered in front of the fore wing. The family Lasiocampidae is practically cosmopolitan but is best represented in the tropics; it includes about 1500 species placed in roughly 150 genera.

Superfamily: Bombycoidea

Family: Saturniidae (Giant Silkworm Moths)

Members of the Saturniidae are medium-sized to very large moths, with wingspans of about 30 to 280 mm. The largest specimens are in the genus *Attacus* from Southeast Asia. Wing spans ranging from about 60 mm (small *Hemileuca* specimens) to 140 mm (large *Antheraea* examples). The body is heavy and covered in hair-like scales. The ground colour of the wings is highly variable, but mostly is some shade of brown; many species have concentric-ringed eyespots (thus the family name). The fore wing ante- and postmedian lines and the submarginal band on the hind wing are perhaps the most characteristic features of the colour pattern. There is no frenulum. The hind wing has one anal vein; veins Sc and Rs in the hind wing fork at the wing base and are not connected by a crossvein; veins Rs and M1 are not stalked beyond the discal cell. The antennae are normally somewhat plumose, especially in males; each segment has four branches except in *Hemileuca*, where there are two. The mouthparts are reduced and non-functional. Larvae often have tubercles or spines on the body; the pupae usually are enclosed in a silken cocoon, often incorporating leaves. Adults are usually nocturnal, although

some Saturniinae and many Hemileucinae fly in the daytime; Temperate species usually overwinter as a pupa, although some do so in the egg. The pupal cocoon may be aerial, attached to a twig or leaf of the hostplant, or spun in the leaf litter, or less frequently in the soil; subterranean pupae may lie in a silk cell or may directly burrow in the earth, as is often the case in *Hemileuca*. This genus has successfully adapted to the dry grasslands and deserts of the American West. The main commercial production of silk comes from *Bombyx mori* (Linnaeus) in the family Bombycidae, which has been domesticated for about 4000 years. However, saturniid moths in genera such as *Samia* and, especially *Antheraea*, produce commercial amounts of silk, mainly in China and India. In Asian silk-producing countries, dried larvae and pupae of the moths are used as food and larvae are eaten in Africa. The larvae and pupae of *Coloradia pandora* Blake (Hemileucinae), are gathered in large numbers eaten by native peoples in California and adjacent states. Saturniids are seldom serious pests, but *Hemileuca oliviae* Cockerell can cause significant economic damage to the grasses of rangelands. The family Saturniidae is cosmopolitan, and is absent from only the most northerly and southerly regions. It is best represented in the tropics with about 1480 species in 165 genera.

Family: Sphingidae (Sphinx Moths, Hawk Moths)

Members of the Sphingidae are medium-sized to large, heavy bodied moths with long narrow fore wings and relatively small hind wings; wingspan range from about 40 to 140 mm. In the fore wing vein M2 arises a little nearer M3 than M1. Veins Sc and Rs in the hind wing are parallel to end of discal cell and beyond (or may nearly meet); near the midpoint of the discal cell they are connected by an oblique crossvein. Some species have much of wings devoid of scales and resemble bumblebees (*Hemaris*). A frenulum is present but is often rudimentary in the Smerinthinae. The antennae are threadlike or often thickened and somewhat spindle-shaped towards the tip. Sometimes they are comb-like. The eyes lack hairs and ocelli are absent. The proboscis is usually long (sometimes much longer than the body, especially in the Sphinginae) but sometimes is short or vestigial, as in some Smerithinae. Most larvae lack obvious hairs and usually have a spine or button-like process near the end of the body, thus giving them the name hornworms. The sides of larval abdominal segments 1 to 7 in species of subfamilies Sphinginae and Smerithinae bear an oblique stripe. Most species pupate in the soil or in leaf litter; the sheath of the developing proboscis sometimes resembles the handle of a cup or jug. Sphinx moths fly strongly with rapidly beating wings; many feed on flower nectar much as do hummingbirds, probing tubular blooms with the proboscis. They are probably important pollinators of some plants. Some suck oozing tree sap or fluids from rotten fruit. Most fly and feed at dusk or at night, but a few of the most familiar, such as species of *Hemaris* and *Proserpina*, fly during the day. Species in these genera probably mimic bumblebees. Larvae of some species damage commercial crops; for example, *Manduca quinquemaculata* feeds on tomato plants and *M. sexta* on those of tobacco. Larvae often rear up when disturbed and, in this position, have reminded some imaginative people of the Sphinx of Egypt. About 1200 species of Sphingidae are placed in 200 genera worldwide. The well-known *Manduca quinquemaculata* (Haworth), from a predominantly Neotropical

genus, is usually called the Five-spotted Hawk Moth because of the five yellow pairs of marks on the abdomen. The larvae feed on tomato and other plants in the Solanaceae and give the species its other English name, Tomato Hornworm.

Superfamily: Noctuoidea

Family: Noctuidae (Owlet, Tiger, Tussock Moths and Relatives)

The classification of the Noctuoidea has undergone recent radical change and former familiar families such as Nolidae, Arctiidae and Lymantriidae are placed as subfamilies with the traditional Noctuidae to form a new, larger and more unified family Noctuidae. This taxon is equivalent to the group known as the quadrifid Noctuoidea and its designation as a family resolves all sorts of thorny problems that once plagued Lepidoptera taxonomists. The family is mainly defined as a group in which vein M2 in the fore wing lies in the lower part of the discal cell so that the cubital vein appears to have four branches. The Noctuidae in the former, more restricted sense (called owlet moths here) vary in size and coloration but, at least in North America, most are heavy bodied moths with wingspans ranging from 20 to 80 mm (up to at least 150 mm in some tropical species); the fore wings are usually finely mottled or figured in browns and greys and the hind wings are pale and more unicolourous. Many species defy this pattern, however. For example, many forester moths such as species of *Alypia* are normally black with white or yellow spots and most underwings (Catocala) have the hind wings brightly banded black and red, yellow or white. Ocelli are almost always present and the antennae are usually thread-like, but can be sawtoothed or comb-like. The proboscis is normally well developed. An epiphysis is present; the tibial spur formula is 0-2-4 and the tibiae and tarsi sometimes bear spines. Some tropical species pierce thick-skinned fruits to feed on juices and the Southeast Asian *Calyptra eustrigata* Hampson and some close relatives suck blood from mammals. Most owlet moth larvae are naked or clothed in fine, sparse hairs; a few, such as some *Acronicta* and *Panthea*, are more densely hairy like their relatives, the tiger and tussock moths. A few noctuids have been used in biological control; for example, *Calophasia lunula* (Hufnagel) was introduced to North America to combat the invasive weed *Linaria vulgaris* P. Mill. (Common Toadflax). The family Noctuidae as defined in Kristensen (i.e. without nolids, arctiids, lymantriids and pantheids) consists of more than 35,000 described species in at least 4200 genera, and was the most diverse family in the Lepidoptera including the Nolidae and Erebidae.

Family: Arctiidae (Tiger Moths)

The Arctiidae gets its English name, "tiger moths", from the colourful, striped and spotted adults of many species. The often densely hairy caterpillars provide the scientific name, which comes from the Greek arktos, or "bear". The word also, of course, means "north" -- home of the "Great Bear" constellation, which points to the North Star. Until recently, the group was given family rank; some species are among our most recognizable moths. Adults are small to medium-sized moths (about 12 to 80 mm in the North American fauna), often heavy-bodied and coloured in spots and bands of black, brown, white, pink, red, yellow and orange. Many are mostly white. The antennae are normally narrowly featherlike or haired in males, threadlike in

females. Ocelli are present, often very small and hard to see, or absent. The proboscis is small or absent. The tarsal spur formula is 0-2-4 or 0-2-2. Vein Cu in the hind wing appears 4-branched and Sc and R are fused to about middle of discal cell; ctenuchids lack Sc+R1 in the hind wing. In females dorsal eversible pheromone glands are associated with the anal papillae and both sexes of most groups have sound-producing tymbal organs on the metathorax. Most larvae are densely tufted with hairs and bristles (some are the familiar "woolly bears"); they pupate in cocoons made of felted larval hairs and little silk. Larvae are mostly gregarious in their early stages and usually become solitary as they mature. Many overwinter as larvae and are familiar sights in autumn when they wander in search of shelter. Many species of Arctiidae feed on grasses and other low plants; others are tree and shrub feeders. Some eat fungi and detritus such as fallen flowers and leaves. Lichens are the main food of the footman moths (Lithosiini), which are usually smaller and less flamboyantly coloured than many of the more striking Arctiini. Tiger moth larvae frequently eat plants containing alkaloid poisons. Larvae and adults may sequester these chemicals for defence against predators; many species exude distasteful liquids from prothoracic glands. The bright colours of many adults and larvae warn potential predators of the presence of these chemicals. Some males use the poisons to construct the pheromones used in mate attraction and, in some cases, they transfer these chemicals to the females during mating in order that the females and their eggs are also protected. Warnings are not restricted to coloration or form. Many nocturnal species produce clicking sounds with their tymbal organs when they detect bats nearby, warning the bats of the moths' distastefulness. These sounds also may subvert the bats' echolocation system and confuse the bats as to the location of the moths. Sounds from the tymbal organs are probably also used in mate attraction. Tymbal organs are reduced or absent in dayflying species such those in Ctenucha, Cisseps and their relatives; however, mimicry of Hymenoptera is frequent these "wasp moths", which are especially diverse in the Neotropics. For example *Lophocampa argentata* (Packard) (Silver-spotted Tiger Moth) attacks Douglas-firs and other conifers, sometimes resulting in aesthetic damage to ornamental trees. *Tyria jacobaeae* Linnaeus (Cinnabar Moth) has been introduced to various parts of North America to control Tansy Ragwort (*Senecio jacobaeae* Linnaeus), a plant poisonous to livestock;

Family: Lymantriidae (Tussock Moths)

The Lymantriidae (=Liparidae) are mostly medium-sized to large moths, with a wingspan of 15 to at least 115 mm; colours generally range from white to brown. The adult male resting posture is characteristic - the wings are held in a broad triangle and pressed to the substrate while the densely hairy forelegs are extended in front of the head. In the hindwing M1 is often stalked with Rs beyond the discal cell; the base of M2 is normally closer to M3 than to M1. There is a trend towards flightlessness in females; for example, *Orgyia* females are large bodied but wingless. There are no ocelli and males have plumose antennae, each branch bearing one to three apical, bristle-like spinules. Some genera have tufts of spoon-shaped scales on the top of the mesoscutellum and the basal abdominal segments; some females have large hair tufts at the tip of the abdomen. The larvae have long,

abundant hair, frequently with clumped needlelike spines; two anterior and two or three posterior pencils of long plumose hairs may be present, as well as short, dense tufts on the top of at least the first four abdominal segments. Some of the hairs may be irritating. Species with larvae bearing irritating hairs incorporate these hairs into the cocoon and emerging females then use them to cover the egg mass. In some species newly hatched larvae feed in aggregations, their protected bodies covered in the toxic scales that were deposited on the egg clusters by their mothers. Wingless females obviously cannot fly, but many fully winged species, such as *Lymantria dispar*, can only flutter weakly along the ground. Most species are nocturnal, but males of some species, such as *L. dispar* and *Orgyia pseudotsugata* (McDunnough), fly during the day or evening.

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02. ORDER DIPTERA (FLIES)

From the Greek *di* = two and *ptera* = wings. Flies have only one pair of wings - the front pair, on the mesothorax. Flies are minute to large insects (about 0.5 to 60 mm long), extremely variable in form and colour, but are mostly rather soft bodied, flying forms. The compound eyes are usually large, often occupying most of the head. They may meet on the top of the head or may be well separated; often, in the same species, the males show the former condition, the females the latter one. Typically, three ocelli occur, but these are reduced or lost in many groups, such as the aquatic families of Nematocera. The antennae are extremely variable in form and consist of three to forty segments. The simplest, basic nematoceran type is thread-like and 16-segmented; the basic number of segments in the Brachycera is eight, but is reduced to four in the higher Diptera. In most of the latter flies, the third segment is enlarged and the more apical segments are reduced to an appendage -- called a stylus when rigid and an arista when bristle-like. Mouthparts are modified and combined into a sucking proboscis, which is highly variable in structure. The ancestral condition is evidently the piercing and sucking type proboscis, more modified proboscis' forms rasp or sponge fluids. Some species have non-functional mouthparts. No flies bite in the true sense of cutting food between mandibles; biting flies pierce the skin of their victims and suck or lap up blood. Diptera are primarily aerial insects and the mesothorax, which bears the only pair of wings, has come to dominate the thorax -- the prothorax and metathorax are greatly reduced. The legs are normally rather simple and are used primarily for perching; in some groups they are modified for prey capture or for signaling during courtship. The tarsi are nearly always 5-segmented. The functional wings are membranous and their pattern of veins is critical in fly classification and identification. During the evolution of flies there has been a trend towards a reduction in veins, especially in the rear half of the wing -- changes that evidently relate to improvements in two-winged flight. The hind wings, present in most other insects, are reduced in Diptera to small, club-like organs, called halteres, used for stabilizing flight.

Flies are holometabolous insects and the larvae typically live completely different lives than the adult insects do. The larvae eat to grow and to provide reserves for adult activity; the adult is primarily a reproductive and dispersal stage. The larvae never have jointed thoracic legs, but sometimes have fleshy prolegs or pseudopods that allow them to move by pushing against surfaces around them. Nematoceran species usually have a complete, well-sclerotized head capsule, but this is reduced drastically in the maggots of higher Diptera to an internal skeleton supporting the hooked mandibles and pharynx. The pupa is usually immobile, although those of some aquatic Nematocera (e.g. mosquitoes) actively swim. In some flies, larvae are deposited after they hatch inside the female; in others, notably the bird and bat parasites in the families Hippoboscidae, Nycteribiidae and Streblidae (but also in the tsetse flies (*Glossina*)), there are no free-living larvae -- the larvae are fed glandular secretions inside the adult female and are dropped only when ready to pupate. At the other extreme, the larvae of some gall midges (Cecidomyiidae) give birth to other larvae (paedogenesis). The Order Diptera is usually divided into two suborders, the Nematocera and the Brachycera. Among the main differences are the

structure of the antennae, maxillary palps and larval mandibles. The basic number of segments in the antennal flagellum of the most ancestral Brachycera is eight. Most nematocerans have more than eight segments in the flagellum and having fewer is considered a secondary reduction. All Brachycera have two or fewer segments in the maxillary palp while the basic number in the Nematocera is five. The mandibles of brachyceran larvae lie parallel and move vertically; those of the Nematocera are opposable and move horizontally. The Brachycera are further divided by major evolutionary steps such as the development of a puparium (pupation within the hardened final larval skin) and the subsequent evolution of an eversible sac (ptilinum), which is extruded through sutures above and beside the antennae and forces the top of the puparium open, allowing the adult fly to emerge.

About 150,000 species of living Diptera have been described in approximately 10,000 genera and 150 families; this is about 14% of the world's known insect fauna. The true number of fly species is probably many times more than this. The larvae of the earliest flies probably fed on damp, decaying plant material, a ubiquitous food source over much of the Earth. Flies then colonized both wetter and drier habitats, leading to life in aquatic and terrestrial environments. Many are predators, parasites and parasitoids, feeding on everything from microscopic animals to mammals; many eat decaying organic matter and plant material. Unlike the adult stages of many beetles and bugs, adult Diptera have not successfully colonized underwater habitats, but many aquatic or semiaquatic larvae are common in fly families. They live from the intertidal waters of the ocean shores to the salt-encrusted margins of desert alkaline lakes, from rushing glacial torrents to the bottom of deep lakes. Many of these larvae, such as those of mosquitoes, horse flies and soldier flies, breathe atmospheric air through open spiracles and must come to the surface periodically. Others, such as chironomid midges and black flies, take oxygen from the water through their integument. Still others live in wet mud or sand or under thin films of water. Those groups, mostly in the higher Diptera, that evolved towards drier habitats live in soil and sand, in leaf litter, under bark, in wood and fungi, in decomposing material or inside growing plant tissues such as roots, stems, fruits and leaves. Some live as ectoparasites on the skin of vertebrates. Secondarily, many returned to a more fluid habitat, such as those in the syrphid, subfamily Eristalinae, where rat-tailed maggots live in semi-liquid, decaying material; in the Ephydriidae, where larvae of one species lives in crude petroleum; and in the Oestridae that are obligate parasites inside the bodies of mammals. Adult flies feed on a wide variety of substances although some have non-functional mouthparts and do not feed as adults. Most eat liquid food: water; decomposing organic matter; animal and plant secretions such as insect honeydew and flower nectar; animal tissue fluids, including vertebrate blood; soluble solids liquefied by saliva. Flies are ubiquitous and are abundant in individuals as well as in species number. They are important food for other animals. Many are parasitic or predatory on other insects and help keep their populations under control. Some herbivorous flies have been successfully used to control weeds. Many are probably important pollinators of plants; certainly a few important crops such as cacao and rubber depend on pollination by ceratopogonids. Many are invaluable as scavengers and are vital in aiding the never-ending decomposition of plant and animal material.

Family: Tipulidae (Crane Flies)

Crane flies are normally slender, very long-legged flies with wingspans ranging from 5 to 85 mm. The head is variable in shape, often expanded forward into a snout-like rostrum. The antenna is usually short or moderately long, but sometimes extremely long in males, reaching four times the body length in some species. The number of antennal segments range from 5 (some *Chionea*) to 39 (some exotic species), but usually there are 13 in the subfamily Tipulinae and 14 to 16 in the subfamily Limoniinae; antennal segments are sometimes branched in males, but rarely branched in both sexes (*Ctenophora*). The eyes are large, usually separated above, but sometimes joined (*Limonia*); ocelli are absent. Thorax with distinctive V-shaped transverse metanotal suture. The long legs are unusually brittle, easily breaking between the trochanter and femur. The wings are elongate, rather narrow, reduced or lost in females of some groups, sometimes in both sexes (*Chionea*). The venation is normally characterized by two anal veins, 9 to 12 veins reaching the wing margin, the basal cells extending at least half the length of the wing, and a distinctive region near the outer third of the wing where the branching points of Rs, M and CuA often occur together in a transverse line. Crane flies occur almost everywhere insects live, from lowland deserts and tropical forests to the high Arctic islands and high mountain tops. Most live in moist temperate forests, especially in cool, damp places near water. Larvae develop in fresh water, especially fast streams, in the intertidal zone, in mosses, decayed wood, wet leaf litter, organic soils and mud, dry soils, fungi, vertebrate nests and in the leaves of terrestrial plants. They are herbivorous, saprophagous or carnivorous.

Crane flies comprise the most speciose family of Diptera – approximately 15,270 species are described. *Tipula*, with well over 2000 named species and *Limonia*, with about 200, are among the most speciose genera of Tipulidae.

Family: Bibionidae (March Flies)

March flies are dark, stocky, somewhat setose flies, about 5 to 12 mm long. Females' heads are rather flattened, more elongate than males; the eyes are small and widely separated. The compound eyes of males meet on top of the head, often covering much of it; the upper two-thirds have large facets, the lower third has smaller ones. Ocelli are present and prominent. The antennae are usually short with 9 to 12, normally rounded, compact segments; *Hesperinus* is the exception; the antennae are long with elongate segments. The scutum is prominent, domed. Femurs often swollen, especially the front pair; front tibiae with apical spurs or rings of spines in *Biblio*, *Bibiodes* and *Dilophus*. In the wing, R₁ ends just beyond the end of Sc; Rs simple or forked; crossvein r-m at or beyond the middle of the wing. Medial vein is two-branched, CuA₁ and CuA₂ reach the wing margin and A₁ is usually weak. There is frequently a pterostigma. The Bibionidae is a common, worldwide family, with about 700 described extant species in six genera.

Family: Mycetophilidae (Fungus Gnats)

Fungus gnats are slender to moderately robust flies, 2.2 to 13.3 mm long. Body usually dull yellow, brown or black, but sometimes brightly coloured. Head

usually flattened front to back, and inserted well below level of upper margin of strongly arched thorax; eyes usually densely setose, usually situated on lower part of head, and never meeting above antennae; usually with three ocelli; frons between ocelli and antennal bases usually bare; antennae inserted at middle of head, and with length varying from scarcely longer than head to several times length of body; antennae beyond basal two segments usually cylindrical, sometimes thickened basally and tapering to apex, and usually composed of 14 segments; labella usually large and fleshy. Thorax varying from compressed and deep to depressed and low; thoracic vestiture variable, consisting of moderately strong bristles with apex bifid or otherwise modified, scale-like setae, or very fine appressed or erect setae; setae or bristles always present on pronotum, scutum and scutellum, but only occasionally present on other thoracic sclerites. Wing veins often with setae; membranes usually densely clothed with microtrichia, and often also with many macrotrichia; R with three or fewer branches; usually with fork of M much longer than stem, and lanceolate rather than bell-shaped. Legs with coxae long and stout; femora usually slender, sometimes swollen, with variable vestiture; tibiae usually slender, with variable vestiture, short setae arranged irregularly or in regular rows, and with bristles variable; tibiae usually with long, strong apical spurs; tarsi usually slender, sometimes with modified setae ventrally, or with some segments swollen below in female; tarsal claws rarely simple, usually with one or more teeth below. Abdomen usually broadest in middle; terga and sterna 1-6, 1-7 or 1-8 in male, and 1-7 in female well developed, but sternum 1 often reduced in size. Male with sclerites of segments 7 and 8 short and telescoped into segment 6; terminalia usually symmetrical. Mycetophilids are usually found to be most abundant in humid or moist habitats in wooded areas. Many larvae live in fleshy or woody fungi, on or in dead wood, under bark, or in nests of birds or squirrels. Most or all of these are probably myctophagous, hence the common name, but some members of the subfamily Keroplantinae seem to be predominantly predaceous.

Family: Cecidomyiidae (Gall Midges)

Gall midges are very small fragile flies, usually 1.0 to 5.0 mm long. Head with large eyes, holoptic or nearly so in both sexes; antennae usually long, usually with 12 or 14 segments beyond the basal scape and pedicel; mouth parts with generally fleshy labella, one to four segmented palps and labrum, the labrum and labella occasionally enlarged and styliform. Thorax about as long as high; mesonotum convex, usually with two median and two lateral rows of setae. Wing with microtrichia, often as scales, and occasionally with macrotrichia; wing veins generally weak, reduced in number, costal vein usually continuous around wing, usually with a break just beyond insertion of R₅; R₅ unforked. Legs usually long with coxae conspicuous; tibial spurs absent; claws toothed or untoothed. Abdomen elongate-cylindrical in male, elongate-ovoid in female; posterior end of female abdomen often protrusible, sometimes very long, and in some groups variously modified for piercing plant tissue. Adults of the subfamily Lestremiinae often fly in cool weather, and can be found at lighted windows at night. The larvae are terrestrial and mycetophagous, usually found in decaying vegetation and wood, in plant wounds, and in mushrooms. Aphids and psyllids are usually the insects

attacked by the internal parasitoid cecidomyiids. There are over 5000 described extant species of gall midges worldwide.

Family: Psychodidae (Moth and Sand Flies)

Moth flies are small, densely setose flies, with a rather moth-like in appearance, and with characteristic short and erratic flight. Head with antennae longer than the head, and sometimes longer than the body; antennae with 12 to 16 segments, each segment usually with dense cupuliform whorls of setae, and with membranous thin-walled sensilla that may be broad or slender, and that may be unbranched or with two to many branches; eye bridge absent or incomplete; mouth part palps with 3 to 5 segments, the next to last segment with a sensory pit or a compact group of sensoria; proboscis usually very short, but in blood-sucking species can be as long as height of head. Thorax with pronotum bare or setose; postnotum bare; pleural sclerites variously setose or bare; transverse suture of scutum not V-shaped; metanotum usually large and projecting over abdomen. Wings usually broad, and held roof-like or flat over abdomen when at rest; longitudinal veins of wings usually well developed; crossveins absent or restricted to basal half of wing; costal vein continuing around wing. Abdomen with sternum 1 sometimes unsclerotized; sternum 2 entire and divided into several sclerites, or unsclerotized. Males with terminalia permanently inverted. Adult flies are usually to be found in moist protected areas, and are mainly active nocturnally. During the day, adults usually rest in shaded habitats. Adult food habits are unknown, except for the blood-sucking habit of female *Phlebotomus*. In the tropics, species in this genus are the vectors of several diseases, such as leishmaniasis. There are several thousand described extant species of moth flies worldwide.

Family: Culicidae (Mosquitoes)

Mosquitoes are delicate, long-legged, slender flies, 3 to 9 mm long and with scales usually clothing most of the body, legs and the veins and hind margin of the wings. These scales vary in colour and often form patterns that are useful in species identification. The head is globose and the compound eyes are concave medially where they meet the bases of the antennae. Ocelli are absent. The first segment of the antenna is small, the second large and spherical and the other 13 are slender and bear a whorl of setae; these setae are longer and more abundant in males than in females. The mouthparts are elongate, stylet-like and enclosed in a sheath formed by the labium. In the male, the maxillary palp is about as long as the proboscis. The wings are narrow, long and lie flat above the abdomen when at rest; there is no discal cell and the single vein R_{4+5} lies between two branched veins – R_2 and R_3 in front and M_1 and M_2 behind. Mosquitoes are common, widespread and well-known insects. Few insect groups have been studied so much. Females of most species bite and feed on the blood of vertebrates, but males do not, and not all biting species feed on humans. Some mosquitoes transmit disease organisms to humans and other animals – malaria, filariasis, yellow fever, dengue, encephalitis and West Nile virus. Adult mosquitoes also pollinate many of the plants that they visit, especially various native orchids. Larvae and pupae are aquatic and live in marshes, ponds, pools, water-filled tree holes, man-made containers, and other places where water collects.

They come to the water surface to breathe; most larvae eat organic debris and micro-organisms; a few are predators of invertebrates. The Culicidae is a large cosmopolitan family of about 3560 described extant species in 42 genera. The three species of *Culex* overwinter as female adults. *Culex pipiens* Linnaeus, small and dull brown, is common in houses and breeds in many aquatic habitats, the more polluted the better. *C. tarsalis* Coquillett is common in southern British Columbia, but was rare before the 1950s; it is the principal vector of western equine encephalitis.

Family: Simuliidae (Black Flies)

Black flies are small stocky insects, about 1.2 to 5.5 mm long. They usually are black or dark brown, but colours also range to grey, rust, orange or yellow. The head is rather large and round, with eyes meeting on top of the head in males, separated in females. There are no ocelli. The antennae are short and thick, with 9 to 11 bead-like segments. The thorax is often strongly arched dorsally, especially in males; it is usually covered with short, dense, recumbent setae. The scutellum is also prominent, more or less triangular and densely clothed in long setae. The legs are short and rather stout; the front tibia has an apical spur, the others have two. The first segment of the tarsus is elongate, that of the hindleg is often swollen in males. The wing is broad with strong anterior veins and weak posterior ones. Vein Rs is simple or has a long fork; rarely the fork is short and obscure. There is a characteristic false vein (m-cu fold) that is usually forked apically, but is unbranched in *Parasimulium*. Vein CuA2 normally is strongly sinuate. Black fly females usually have mouthparts structured to cut skin and suck blood, but in some females and all males they are weak and only usable for imbibing fluids such as water and nectar. However, not all species bite humans and some eat no blood at all. Those that do bite can be serious pests of man, other mammals, and birds. Simuliid bites are irritating and often cause infection and allergic reactions. Through blood feeding, many species transmit parasitic disease organisms among birds and mammals; the worst is the filarial nematode that causes human onchocerciasis in the tropics of Africa and the New World. Larvae live in flowing water, attaching themselves by the tip of the abdomen to a pad of silk they fix to submerged objects. Most feed by filtering food out of the water with fan-like mouthparts; some lack these labral fans (e.g., *Gymnopsis*, *Twinnia*) and graze off the substrate. The Simuliidae is a relatively small, homogeneous family of almost 1800 described living species;

Family: Ceratopogonidae (Biting Midges, No-See-Ums)

Flies of the family Ceratopogonidae are minute to small 1 to 6 mm long, (most in BC are about 2 mm long) and slender to rather stout. The compound eyes usually meet, or almost meet, on top of the head (but well separated in Leptoconopinae); they are usually bare, but sometimes are finely setose. There are no ocelli. The antennae have 8 to 15 segments, although vertebrate feeders have 13 to 14 (*Leptoconops*) or 15 (other genera); females have the last five segments elongated (in the Leptoconopinae only the last one is differentiated) and most males have plumose antennae. The proboscis is about as long as the head; most females have serrate mandibles. A pair of humeral pits often occur near the front edge of the mesonotum. The wing typically has one to three compacted radial veins close behind the front

edge of the wing and reaching the wing margin before the wing tip; two median vein branches reach the wing margin; crossvein r-m usually strong. The wings overlap over the abdomen when at rest, often patterned with dark or light spots or patches. The females of predatory Ceratopogoninae usually have at least one pair of raptorial legs with swollen, spiny femora or with enlarged tarsal claws. Biting midges live mainly in moist habitats around the aquatic or semi-aquatic environments where the larvae live. Most species of *Culicoides* fly at dusk, but those of some genera, such as *Leptoconops*, fly during the day. Females of many species suck blood to provide protein for egg maturation, and many are notorious for both their biting and for transmitting disease. Their small size enables most to crawl through the mesh of screens and, when large numbers of biting females are present, avoiding them outdoors is difficult. *Culicoides* species are vectors of filarial nematodes, blood protozoans and viruses such as bluetongue in livestock. *Culicoides*, *Leptoconops*, *Austroconops* and some *Forcipomyia* are the only genera that feed on vertebrates, usually mammals or birds, but also reptiles, amphibians and even the amphibious mud skipper fish of Southeast Asia. Many *Forcipomyia* drink the blood of large insects such as dragonflies, katydids and butterflies, usually feeding from wing veins. Other species kill small swarming flies and mayflies; some females eat males of their own species. *Dasyhelea* and some other genera feed only on nectar, and many others supplement their diet at flowers. Some are important pollinators of cacao (from which chocolate is derived), rubber trees and other plants. The larvae of the most diverse subfamily, the Ceratopogoninae, run the gamut from burrowers in wet soil and manure to active swimmers in the waters of large lakes and rivers. Many are carnivorous. Those of the Leptoconopinae live in the soil and sand of arid habitats or the beaches of oceans and inland waters, feeding on microorganisms. Forcipomyiinae crawl in moist places such as moss mats or under bark, eating algae and fungi; Dasyheleinae wriggle in the fluids of sap flows, tree holes and other small, wet habitats.

Family: Chironomidae (Chironomid Midges)

Chironomid midges are delicate, small to medium-sized flies (1 to 10 mm long) with long, slender legs and narrow wings; some superficially resemble mosquitoes, but lack the long proboscis. Most are brown or black, but green, reddish and yellow species occur; many have the abdomen and legs banded and some have patterned wings. The compound eyes usually do not meet above; they may be bare or setose. Ocelli are absent, although the frontal tubercles on some species may be modified ocelli. The antennae are 3- to 17-segmented, usually with more segments in males than in females; the antennae are plumose in most males. The mouthparts are reduced, lack mandibles and are non-biting. The thorax is convex or flattened above, the scutellum is hemispherical; the postnotum is large and usually bare and marked with a median longitudinal furrow. The legs often have the tarsus of the foreleg elongate and sometimes strongly setose; the forelegs typically are held up off the substrate. The wings lie flat or roof-like over the abdomen when at rest. The costal vein usually is fused with R_{4+5} near the wingtip, but rarely reaches the wingtip. The subcosta usually ends before reaching the costa. The radius is three-branched, normally more strongly sclerotized than the posterior veins; R_{2+3} is often weak,

sometimes absent, and branches into R_2 and R_3 in the Tanypodinae. The medial vein is straight and unbranched, meeting the wing margin near the wingtip. Vein CuA is forked at, or past, the r-m crossvein and crossvein m-cu is present or absent. Chironomid midges are common and abundant – they are the most ubiquitous freshwater insects. Adults are most active at dusk or at night and at sundown they often form mating swarms that rise and fall over shrubs, rocks and other markers near water. Although they do not bite, their sometimes enormous numbers can be a severe nuisance, especially around lakeside homes and resorts. As in many groups of flies, the immature stages of chironomids are more interesting than the adults. Larvae live mainly in the fresh water of ponds, lakes and streams, but many species occur in brackish habitats or the salty waters of desert and grassland alkaline lakes. A few develop in the marine intertidal zone. Others live in wet soil and leaf litter, in mammal dung and in pitcher plants. They are found from the mud in the deepest lakes to the surface of stones in shallow pools and springs; they tunnel in rotting wood and mine the tissues of aquatic plants; they live, sometimes parasitically, on the bodies of mayflies, stoneflies, molluscs and other organisms. Most chironomid larvae eat detritus and microscopic plants and animals; most live on or in the substrate, usually in tubes made from substrate particles bound with salivary secretions. Others, especially species in the subfamily Tanypodinae, prey on macroinvertebrates such as other chironomid larvae. The Chironomidae is a large and cosmopolitan family of over 5000 species.

Family: Tabanidae (Horse Flies and Deer Flies)

Horse flies and deer flies are medium-sized to large (5 to 30 mm long), rather stout, large-headed flies, black, grey or brown, often coloured in orange or yellow; their bodies are more or less finely setulose, but lack enlarged bristles. The large compound eyes, often brightly coloured, iridescent, striped or spotted, are separated in females, but meet dorsally in males; the antennae are 5 to 11-segmented, the flagellum consisting of a large basal segment and 2 to 8 small annular segments apically. The proboscis is strong and rigid, with knife-like mandibles and maxillae in females of biting species. The large thorax bears stout legs; the front tibia lacks apical spurs, but these occur on the middle tibia and are present or absent on the hind one. The empodium is pad-like. The wing bears large calypters. The venation is rather primitive and uniform; the costa extends around the wing margin and the radius has four branches. A distinctive feature is the splayed veins R_4 and R_5 , which widely straddle the wingtip. The wings are often darkened and patterned distinctively. The abdomen is broad, often strikingly patterned; seven segments are visible. Horse flies and deer flies, because of their fierce biting habit, are familiar to most people who spend time in the summer, outdoors, away from cities and towns. Indeed, these flies are well studied because of their medical and veterinary significance. Apart from the annoyance and loss of blood suffered by humans, domestic and wild animals that the females bite, tabanids are also vectors of microorganisms that cause tularemia, anthrax, anaplasmosis and other diseases. Normally, adults are active only in bright sun on warm, windless days; both females and males visit flowers to feed on nectar. Some species require no blood meal to mature the eggs, but most females suck blood from warm-blooded animals, at least after the first batch of eggs is laid. The compact

egg masses are laid on plant stems or leaves above the larval habitat. The larvae of most species live in the wet soil of marshes, fens, bogs, and along the margins of ponds and streams. A few live in the beds of fast flowing streams and some develop in dry soil. Apparently, most are predators of invertebrates, although *Chrysops* larvae may feed on plant matter in mud. Worldwide in distribution, the family Tabanidae consists of about 4,200 named species in 201 genera; There are three subfamilies: the Chrysopsinae, with hind tibial spurs and an antennal flagellum with five or fewer segments; the Pangoniinae, with hind tibial spurs and eight or nine apparent segments in the flagellum; and the Tabaninae, lacking apical spurs on the hind femur. Deer flies are insects of open woodland, most diverse in north temperate regions, where members of the deer family are common. When biting people, they usually attack the head and neck. Eg., *Tabanus* (*T. Aegrotus*, *T. Punctifer*), *Haematopota* (*H. americanaotus calcar*).

Family: Asilidae (Robber Flies)

Robber flies are named after their predatory habits – they attack and devour other insects. The body form varies widely, from delicate and slender to heavy and stout, from almost bare to bristly or setulose. Some are tiny flies only 3 mm long, but others are gigantic, over 50 mm long. Colours range from browns, greys, silvers and blacks to colourful patterns of contrasting blacks, yellows and reds. Males of some species have additional ornamentation such as the expanded silver abdominal tip in *Nicocles*, the striking white abdomens of *Efferia* and the decoration on the tarsi of many *Cyrtopogon* species. The compound eyes are large usually rather flattened from front to back; in most species the broad forward-facing area has enlarged facets. The compound eyes are well separated dorsally in both sexes by a distinctive hollow. The ocelli are prominent, usually placed on a tubercle. Varying from flat to strongly protuberant, the face bears a characteristic tuft of setulae or bristles, the mystax. The antennae are erect, usually 4-segmented. The first segment of the flagellum is elongate or oval, the stylus is normally 2-segmented, but may be 1-segmented or apparently absent; it is prominent and seta-like in the Asilinae. Both sexes have stabbing and sucking mouthparts developed into a proboscis -- paralyzing saliva is injected through the needle-like hypopharynx (tongue), which is sheathed in the prominent labium. The thorax is prominent and powerful and usually bears distinctively arranged bristles. The legs are strong and raptorial, frequently with numerous bristles; the empodium is bristle-like, but is lost in some Leptogastrinae; the pulvilli are also lost in the latter subfamily and a few other genera. The wings are sometimes coloured or spotted. The venation is not much modified and vein R always has four branches, with R_{2+3} unbranched. However, R_{2+3} joins R_1 before the wing margin in some subfamilies (e.g. Laphriinae, Asilinae), closing cell r_1 . Cells m_3 and cup are often closed. The abdomen varies from cylindrical and tapering to short, broad and rather flattened; in the Leptogastrinae the abdomen is slender, elongate and club-shaped. Acanthophorite spines are present in females of several subfamilies and a prominent knife-like ovipositor is formed from the terminal abdominal segments in many genera of the Subfamily Asilinae. Robber flies are predators that as adults pursue other insects, seize them with powerful legs and kill them with a paralyzing stab of the hypopharynx. The liquefied contents of the prey

are then sucked-up by the proboscis. They are mostly opportunistic predators, feeding upon any insect that they can subdue and kill. Some species, especially in the subfamily Laphriinae, are effective mimics of bees and wasps. Robber flies usually hunt in open areas where there is plenty of light and warmth; grasslands, scrub, deserts and open woodland are the best places to find them. Larvae are predators of the eggs, larvae and pupae of other insects in the soil (most groups) or in rotting wood (subfamily Laphriinae), although in a few species studied the immature larvae, especially, are ectoparasitic on their hosts. The Asilidae is a speciose family of about 6700 described extant species worldwide. Some of examples are *Leptogaster arida*, *Cyrtopogon willistoni* and *Stenopogon inquinatus*

Family: Bombyliidae (Bee Flies)

Members of the Bombyliidae are called bee flies because many, in their setulation and flower-visiting habits, resemble bees in a vague sort of way. In addition, some species develop as parasitoids in the nests of solitary bees. Bee flies are small to large flies (1 to 25 mm long), with the usually stout body normally clothed in delicate setulae or scales, or both, ranging in colour from black and brown to white, silver and gold. The wings are often patterned and colourful. The compound eyes are globular to transverse, without setae, often meeting dorsally in males. In some groups, especially the subfamily Anthracinae, the hind margin of the compound eye is sharply indented, with a horizontal seam dividing the facets. There are three ocelli. The back of the head is flat, swollen or deeply concave (e.g. subfamily Anthracinae). The mouthparts are adapted to sucking from flowers: the proboscis is long and slender (e.g. Subfamily Bombyliidae) or short and with fleshy labella (e.g. subfamily Anthracinae). The antennae have 3 to 6 segments; the first segment of the flagellum is enlarged and the others, if present, form a stylus. The thorax is flattened or humped, with or without bristles; the latter are seldom strongly developed. The legs are slender, with or without bristles, but normally with bristles at the apex of the tibiae. The front legs are often thinner, shorter and weaker than the other two pairs, especially in anthracine genera such as *Exoprosopa* and *Poecilanthrax*. The wing venation is variable. Vein Rs normally has three branches (R_{2+3} , R_4 and R_5), with R_{2+3} usually ending in the wing margin toward the wing tip (and along with R_4 often bent sharply forward), but sometimes short and joining R_1 . Vein M usually with two branches reaching the wing margin; occasionally only one branch is complete because M_1 ends in R_5 or because M_2 is absent. Cell dm is usually present and cell cup is open or closed. The abdomen is short and broad, elongate or cylindrical, consisting of six to eight visible segments and seldom bearing bristles. The females of many bombyliid groups have acanthopores and spines on the tenth segment, but many have lost these egg-laying aids. Females in advanced groups, including the subfamilies Bombyliinae and Anthracinae, have a sand chamber, developed through modification of segment 8, in which eggs are coated with sand from the substrate before they are laid. Bee flies are sun lovers and are most diverse in hot, dry climates where sand and stony ground prevails. They have a strong, hovering flight and usually are seen around flowers or hovering over, or resting on, bare patches of ground. They feed on nectar and, perhaps, some pollen from the flowers they visit. When perched, they hold their

wings outstretched and swept back. Not much is known about the development of most species; those that have been studied are parasitoids of the immature stages of bees, wasps, moths, beetles, flies and other insects or they prey on the egg pods of grasshoppers. Eggs are laid near the host insects and the larvae are similar to those of the related Nemestrinidae and Acroceridae – an active first-instar larva seeks out the food source and moults to a grub-like form in subsequent instars to feed voraciously on the host. The Bombyliidae is a worldwide family with about 4700 species described in 230 genera eg., *Bombylius major*

Superfamily: Syrphoidea

Family: Syrphidae (Flower or Hover Flies)

Slender to robust flies, 4 to 25 mm long, with body usually black and strikingly marked with yellow or orange on the head, thorax and abdomen. Many such species are mimics of bees and wasps. Less commonly, species are brown, yellow or metallic green or blue, or with various combination of such colour. The integument is usually smooth, but sometimes is totally or partly punctate, sculptured or rugose, and may be somewhat pruinose. The body is usually covered with dense, short setae, but rarely may be almost bare, or with long setae or stout bristles. The setae are sometimes flattened or scale-like, forming a dense tomentum. The compound eyes are usually holoptic in males, but can be very narrowly or broadly dichoptic. Females are moderately to broadly dichoptic. Some or all of the facets in the upper part of the compound eye may be enlarged in the male. However, the eyes are usually unicolourous, but rarely can have dark spots or bands, or have irregular markings, and may be bare or setose, with short or long, sparse or dense, setae. Three ocelli are present, and the antennae are sometimes set on a short or long frontal prominence. The lower facial margin usually has a distinct median notch. The arrangement of thoracic bristles or setae is important taxonomically. The wings are usually hyaline, but sometimes are somewhat darkened or with distinct markings. Characteristically, these flies have the costa ending at the apex of R_{4+5} , and there is an unattached longitudinal vein, the spurious vein (*vena spuria*), running most of the length of cells br and r_{4+5} , posterior to Rs . The apex of vein M is bent strongly forward near the wing margin, and joins near the end of R_{4+5} , thus forming an apical crossvein. Cell *cup* in the wing is closed near the wing margin, and a pterostigma is usually present. The legs are usually slender, but can be somewhat modified, especially in males. The abdomen is usually suboval, but can be elongate or even petiolate. Adults lay oval, chalky-white, sculptured eggs on or near the food of the larvae, those with aphidophagous larvae being laid singly, but others may lay eggs in masses of over 100. Larvae have a wide variety of habitats and food. Some are predaceous (Syrphinae, Pipizini), but others are phytophagous (*Cheilisia*, Merodontini), saprophagous (most Eristalinae), or scavengers (*Volucella*, Microdontinae). The mouth parts of such larvae are thus quite different. Predaceous types have four stylets for piercing and sucking, while phytophagous forms have strong mandibles. Saprophagous species have a complex comb-like mandibular lobe, and like the scavengers, have a muscular and contractile cibarial chamber.

The predaceous larvae of the Syrphinae feed primarily on aphids and other Homoptera, but some species have been reported to feed on immature thrips, beetle,

or lepidopterous larvae. Larvae of the Pipizini feed on aphids, preferring woolly or root aphids with a waxy integument, and attack these living both above and below ground. Larvae of the Syrphinae and Pipizini are thus important in natural biological control. The phytophagous larvae of *Cheilisia* feed in fungi or vascular plants, while the larvae of the Merodontini live in monocotyledonous bulbs, and sometimes in other plants, and may cause considerable economic damage. Worldwide there are some 180 recognized genera, and about 6000 species.

Superfamily: Muscoidea

Family: Scathophagidae (Dung Flies)

Scathophagids are slender, small to medium-sized flies (about 3 to 11 mm long); bristling ranges from weak to strong and some species are densely setulose. The ground colour is usually black, brown or yellow, but some are strikingly bicoloured; some are densely grey or yellow pruinose. The head is normally higher than long, with the frons of equal width in males and females. There are 1 to 3 orbital bristles and 1 to 6 frontal bristles; the latter are curved inward. Also present are ocellar, postocellar and inner and outer vertical bristles. The parafacial area is bare; the vibrissa is weak or strong and there are few to many weaker bristles and setulae nearby. The compound eyes are bare. The second antennal segment has a distinct seam above; the third segment is two to five times longer than wide, usually rounded at the tip and sometimes with a long bristle near the base of the arista. The arista is three-segmented, straight or rarely elbowed, and bare or feathery. The bristles of the thorax are normally rather strong, but those on the disc of the scutum are sometimes short and setae-like. The postpronotum usually has one or two bristles; there are normally two presutural and three postsutural dorsocentral bristles. The scutellum rarely has more than two pairs of marginal bristles. The wing venation is rather constant; the costa has costagial, humeral and subcostal breaks, the subcosta is complete and vein R_1 joins the costa before the middle of the wing. Vein R_{4+5} meets the costa at about the wing tip and the costa ends at vein M_1 . Vein A_1 is usually complete, but sometimes ends before the wing margin. The wings are normally clear, but sometimes spots or bands occur. The legs are slender; bristles vary from weak to strong. The front femur and tibia sometimes bear short black setae below and are sometimes highly modified in males. The abdomen is slender, but in males is frequently enlarged at the tip; the first and second tergites are fused. Only some species of dung flies develop in dung. Larvae of the large and common genus *Scathophaga* Meigen mostly do so, although some larvae feed in rotting seaweed on ocean beaches. Other Scathophaginae feed in a wide range of plants, especially monocots including *Scirpus* Linnaeus and *Juncus* Linnaeus. Still others are predators in water, wet soil or plant tissues. Larvae of the subfamily Deliniinae mine in the leaves of plants in the lily and orchid families. Adults prey on insects and other small invertebrates. The Family Scathophagidae has often been treated as part of the Anthomyiidae or Muscidae. Its approximately 260 named species are almost completely restricted to the Holarctic region

Family: Muscidae (Muscid Flies)

Muscid flies are slender to stocky, 2 to 14 mm long and usually bristly. Their colour ranges from yellow to grey or black, but some are metallic blue or green. In a few cases the flies are brightly setulose. The wings are usually unmarked, but some have clouded crossveins. The head is usually higher than long with the frons in males narrow to broad and its central plate sometimes strongly reduced; the frons in females is at least 25% as wide as the head with the central plate always distinct and normally wider than the fronto-orbital area. There are one to many frontal bristles curved inwards. The parafacial area is usually bare, but the vibrissa is normally strong and has associated bristles or setulae. The face is usually flat or concave, rarely with a medial ridge or tubercle on the upper part. The third antennal segment is at least twice as long as broad and usually rounded at the tip; the arista is 3-segmented, bare to plumose or rarely comb-shaped. The thoracic bristles are usually long and prominent; there are normally 1 to 2 presutural and 3 to 4 postsutural dorsocentral bristles. The scutellum usually bears two pairs of marginal bristles; there is rarely an isolated group of setulae on the underside of the apex. The costa has costagial, humeral and subcostal breaks; the costa usually ends where vein M_1 meets the margin. Vein M_1 is more or less parallel to vein R_{4+5} or is bent forward; vein A_1 never reaches the wing margin. The legs are usually slender with varied bristling; the base of the first tarsal segment of the hindleg lacks the distinctive ventral bristle characteristic of most anthomyiids. Both sexes have five exposed abdominal tergites usually bearing strong marginal bristles. Larvae develop in many habitats, from dung and decaying plant matter to carrion and fungi. They are found in the nests of bees, wasps, birds, mammals and other animals. Others live in fresh water or soil of many sorts; a very few develop in living plant tissue. Most evidently feed on excrement, decaying organic matter and the micro-organisms that inhabit this material; some are known as predators of insect larvae or other invertebrates. A few species such as *Fannia canicularis* (Linnaeus) (Lesser House Fly) and *F. scalaris* (Fallén) (Latrine Fly) can invade the human body and cause intestinal and other myiasis. The food of adults is also varied. They feed on dung or decaying organic matter, plant sap, honeydew and pollen. Some are predators of insects; others suck vertebrate blood or feed on the exudates of mammals and other animals. Those species that feed on human feces and food, such as *Musca domestica* Linnaeus (House Fly) can spread human diseases such as typhoid fever, cholera and dysentery. Muscid flies are widespread around the world, occurring on all continents and most oceanic islands. About 4300 species in about 180 genera are described with 4 genera and about 270 described species of those in the Fanniinae and the rest in the Muscidae in the strict sense. *Musca domestica* is the notorious House Fly, common now over much of the earth and widespread. *Musca autumnalis* De Geer is a European immigrant, first recorded in North America in 1952; it prefers moist shady pastureland and breeds in cow dung, which the House Fly avoids. Called the Face Fly because it commonly feeds on fluids from the eyes and nostrils of cattle, *M. autumnalis* frequently gains notice for its habit of overwintering in buildings.

Superfamily: Oestroidea**Family: Calliphoridae (Blow Flies)**

Most species of blow flies are stocky, medium-sized to large, 4.0 to 16 mm long, with bodies partly or completely metallic blue, green, black or brassy. Less frequently, they are small, slender and without metallic coloration. The sexes often differ distinctly in colour. The head is distinctly higher than long and the compound eyes in males rarely meet above, although the frons is narrower than in females. The lunule is bare and shining; the frontal setae reach forward to the second antennal segment; the frons usually is finely setulose. The vibrissa is strong and the gena is thickly setulose. Females have one backward-curving orbital bristle above and two forward-curving ones below. Ales lack frontal and outer vertical setae. The antenna has the arista long plumose on at least the basal two-thirds. Thorax with two notopleural setae; usually two or three anterior and posterior dorsocentral bristles are present. The scutellum has one to three pairs of lateral bristles; the apical pair is usually strong. The subscutellum is weakly developed or absent. The wing has the bend of vein M right-angled or acute; cell r_{4+5} is almost always open at the wing margin. Blow flies are predominantly flesh-eaters as larvae. The most familiar blow flies, the common species called bluebottles and greenbottles, lay eggs on carcasses of all kinds and also are attracted to fresh and cooked meats and dairy products indoors. The restless flying around in rooms, so commonly seen, is mainly a search for places to lay eggs. The term "blown" refers to meat that has had blow fly eggs laid on it. The development of some species, such as *Phormia regina* (Meigen) and various species of *Calliphora* Robineau-Desvoidy, on human corpses is frequently monitored in establishing the time of death in murder cases. Some species are also attracted to excrement and can transmit digestive system pathogens. Most economically important are those species whose larvae are called screwworms. The Family Calliphoridae ranges worldwide, with about 1000 described species in 150 genera.

Family: Oestridae (Bot and Warble Flies)

The Family Oestridae contains medium-sized to large (9 to 25 mm long) flies with stout, bristleless, but often thickly setulose bodies. They often resemble bumble or carpenter bees. The head is broad, higher than wide in side view and the flat face is either broad and shield-shaped or strongly narrowed below the antennae. The antennae are small and sunk deeply into pits; the third segment is globular and bears an arista. The arista is either slender and bare with a thickened base or, in *Cuterebra* Clark, feather-like and lacking the broad base. The mouthparts are small and compact, or often atrophied. The thorax is covered in short setulae or is densely long-setulose; rarely there are some weak bristles present. The legs are short, stocky and setulose; the femora and tibiae often bear some weak bristles and the tips of the tibiae and the tarsal segments usually have short, spine-like bristles. Wings with vein M highly variable -- straight or weakly curved, ending at the wing margin well behind the wing tip, or curving forward to join vein R_{4+5} just before the wing margin, or meeting the wing margin immediately behind the tip of vein R_{4+5} , or strongly angled with a prominent stump vein beyond crossvein dm-cu. The abdomen is globose to conical with shiny cuticle and long, coloured setulae or is

partly or completely pruinose. The species of the Family Oestridae are obligate parasites of mammals and most are strongly host-specific. Adults have tiny or atrophied mouthparts and apparently do not feed on sugars or protein as do other calyptrate flies. They rely on fat reserves for energy, although some species of *Cephenemyia* Latreille and *Cuterebra* evidently drink fluids by pressing the underside of the head against a damp substrate. In the subfamily Cuterebrinae the eggs are usually laid in places frequented by the host mammals and the larva enters the host through any orifice, eventually migrating to subcutaneous tissues where it feeds in the warble, a pouch formed in the connective tissue of the skin. The larva breathes through the posterior spiracles, which communicate with the outside air through a small hole in the skin. The position of the warble is often predictable; those of *Cuterebra* in mice and chipmunks are usually on the belly while those in rabbits are normally on the neck. When mature the larva drops from the host and pupates in the soil. Females of *Dermatobia hominis* Linnaeus Jr., which attacks a wide range of hosts (including humans) in the Neotropics, first catches a blood-sucking fly (such as a mosquito), on which she lays her eggs and then releases. When the fly lands on a host to bite, the eggs hatch and the larvae burrow into the host's body. The larvae of *Hypoderma* Latreille burrow into the skin, migrate through the body by various routes to the skin of the back where warbles are formed. Larvae of the Oestrinae live in the respiratory passages of a wide range of hosts including ungulates, horses, elephants and kangaroos. The eggs are retained in the female until they hatch; the young larvae are expelled within droplets of fluid onto the face of the host. In some *Cephenemyia*, at least, the larvae crawl into the mouth and enter the sinuses and throat via the palate. Bot fly larvae feed on blood and mucous and can cause severe damage to the tissues; mature larvae are coughed out of the mouth or sneezed out of the nostrils. The Sheep Nostril Fly or Sheep Bot Fly, *Oestrus ovis* Linnaeus, infests the noses, sinuses and throats of domestic sheep, but evidently has not transferred to native species. It also will attack goats, dogs and, sometimes, even humans. There are some cases of larvae living in the human eye where they can damage the cornea, but apparently there they are unable to develop past the first instar.

Family: Sarcophagidae (Flesh Flies)

Species of the family Sarcophagidae are robust, mostly grey flies ranging from 2.5 to 23 mm long. The thorax is usually has three dark stripes on top and the abdomen is striped, banded or spotted with markings that shift tones depending on the angle of the light. The abdomen is sometimes partly red. The head is wider than high and, in side view, usually a little higher than long. The compound eyes are bare. The fronto-orbital area usually has sparse setulae, but the central part of the frons is normally bare. There about 4 to 10 frontal setae and one to three orbital setae curving backward, two to four curving forward; these last setae are usually missing in males in the Sarcophaginae. The face is concave and lacks a central ridge. Vibrissae are present. The antennal arista is bare or finely setulose (most Miltogramminae) to plumose, especially on the basal half or two-thirds (most Sarcophaginae). On the thorax, there are normally 3 to 4 anterior and 3 to four posterior dorsocentral bristles. The scutellum has 2 to 3 pairs of lateral setae and one

pair of discal setae; if a pair of apical setae occurs, they are small. The wing has the origin of vein R_{4+5} setulose above and below, with the setulae continuing toward crossvein r-m above. Any extension at the bend in vein M is usually not developed, but is merely present as a short, darkened fold. Flesh flies lay larvae or eggs that are ready to hatch. There are over 2500 named species of sarcophagids worldwide, placed in 108 genera.

Family: Tachinidae (Tachinid Flies)

Tachinids are tiny to large flies, often strongly and densely bristled. The head takes many shapes – usually it is higher than long with a sloping frons and small antennae in holoptic males, but ranges to box-like with a horizontal frons, long face and long antennae. The frons of holoptic males is narrow and usually lacks any lower orbital bristles curving forward; almost always two pairs of such bristles occur in females and dichoptic males. Frontal bristles usually bend inward. Ocelli are rarely absent and the ocellar setae usually curve forward. The antennae range from tiny to as long as head height; the second segment bears setae on the front; the arista is normally bare, but sometimes is feather-like. The face is usually concave or flat, but sometimes convex; there is normally a strong vibrissa. In some species the labium is sometimes extremely long and slender. The postpronotum usually has four strong bristles, but there can be as few as two and as many as five. The scutum can be extensively bristled, especially in the subfamily Goniinae to almost devoid of them (many species in the subfamily Phasiinae); there are usually three presutural dorsocentral bristles and three or four postsutural ones. The scutellum usually bears three or four pairs of marginal bristles and one pair on the disc. The subscutellum is well-developed, in side view usually evenly convex from top to bottom. The meron always has a vertical row of bristles. The wings are normally transparent, but some are marked or spotted and others are all dark. Vein M is bent forward, ending in the wing margin just behind vein R_{4+5} or in vein R_{4+5} itself, thus closing cell r_{4+5} . The abdomen is variably shaped, from petiolate to broad, from convex above to flattened to globose. It is usually more or less covered with strong, erect bristles, but these are lacking in some species. As far as is known, all the larvae of the Tachinidae are parasites of arthropods, and all except a few of these arthropod hosts are insects. The family plays a major role in the control of populations of other insect groups and many species have been used in the biological control of insect pests. The vast majority of species in the Tachinidae, however, store the eggs in an ovisac (uterus) until embryonic development is complete. Unlike sarcophagids, which deposit active larvae that have hatched within the female, all tachinids lay eggs that hatch (but sometimes within seconds) after deposition. Most hosts avoid direct attack during the day while female flies are active; either the hosts are concealed in the soil, leaf litter or other substrates or are protected by silken webs, such as those produced by tent caterpillars. There are a very few records of tachinids parasitizing centipedes, spiders and scorpions. Adult tachinids are active and eagerly search for sources of sugar; they are particularly attracted to honeydew. Some, in search of nectar, often visit flowers, especially those of the Asteraceae, and others feed on tree sap. Males of many species congregate on sunny hilltops and ridges to wait for females. Species aggregate at specific sites in these places. In the Diptera, the Family Tachinidae is

second only to the Tipulidae in the number of described species -- at least 8000 species are known worldwide.

Superfamily: Hippoboscoidea

Family: Hippoboscidae (Louse Flies and Keds)

Flies of the family Hippoboscidae are flattened, rather tough and leathery looking flies, ranging from 1.5 to 12.0 mm long. They are usually setulose. The head is broad and somewhat flattened; the mouthparts are thrust forward. The compound eyes are normally well developed and horizontally elongate; ocelli are either present, vestigial or absent. The inner vertical bristles are long, the outer ones are absent and the orbital bristles are few to many. The lunule is usually bare, shiny and conspicuous. The antennae are strongly modified and are more or less immovable; they lie in deep pits. The first segment is usually present, but sometimes is fused to the lunule and invisible; the rounded second segment is the largest and sometimes bears a third, flattened, segment or a spatulate or branching arista. The one-segmented palps form a sheath for the blood-sucking, retractible labium. The thorax is flattened; the scutellum is usually large, often broadly rectangular. The wings are usually fully developed, but in some genera that parasitize mammals, such as *Lipoptena* Nitzsch and *Neolipoptena* Bequaert, the wings break off after the fly settles on its host. In others, the wing is reduced to a small flap or, as in *Melophagus ovinus* (Linnaeus), which lives in the fleece of sheep, is a tiny knob. This species has lost its halteres, but they are normally present in other species. The wing veins are usually crowded forward with the posterior veins often fading towards the wing margin. Some species have greatly reduced venation. The legs are strong, rather short and often well-bristled. The coxae and femora are usually swollen; the apical tarsal segment is the largest. The tarsal claws are large and strong, simple or forked; the empodium is setulose or feathery and the pad-like pulvilli are often long and soft. The abdomen is largely membranous with tergites and sterna mostly reduced.

Hippoboscids are ectoparasites and feed on the blood of birds and mammals. The majority attack birds and are often called louse flies; those on mammals (mostly ungulates) are frequently called keds. The Sheep Ked (often erroneously called the sheep tick) is probably the only species in North America that causes any economic losses; heavy infestations of sheep sometimes result in anaemia and staining of the wool. This species was introduced from Eurasia to sheep-producing temperate environments worldwide and, apparently, no truly wild populations exist today. Those populations found on bighorn and thornhorn sheep are thought to have transferred from domestic sheep. Several species have been recorded biting humans, but this is a rare and accidental phenomenon. Most species are not host specific, but rather seem to inhabit a variety of hosts from a particular type of habitat.

Together, the Hippoboscidae, Nycteribiidae and Streblidae are sometimes called the Pupipara, because they appear to give birth to pupae. This is inaccurate, in that the fully grown larva is extruded by the female and immediately pupates afterwards. One at a time, an egg and then a larva develop in the female uterus, nourished by secretions from the so-called milk glands. A female can produce seven or eight or more mature larvae during her life. The Family Hippoboscidae is

cosmopolitan, but is most diverse in the tropics and subtropics; about 200 species are named in 21 genera.

Family: Tephritidae (Fruit Flies)

Small to medium-sized and often brightly coloured, tephritid flies usually have wings banded or spotted in various patterns. The head is variable; in some exotic species the compound eyes are stalked. Usually one pair of inner and outer vertical bristles occur, along with one pair of postocellars and ocellars and one to several pairs of orbital and frontal bristles. The latter two types of setae are sometimes thickened or flattened. Vibrissae are absent. The second antennal segment sometimes bears a seam on top and the third segment is often pointed on the upper end; the arista is usually bare or finely setulose. The proboscis is sometimes long and elbowed. The scutellum is swollen and shining in some genera, with 1-4 pairs of bristles, normally on the margin. The bristles on the scutum are variable, but there is always at least one pair each of dorsocentral and acrostichal bristles. The wing has a distinctive Sc bent sharply forward toward the costa and weakened after the bend, often not reaching the costa. Vein R_1 always bears short setae above. The cell cup usually has an acute projection on the hind margin. Colour patterns usually present, ranging from almost entirely dark brown or black to combinations of bands, stripes, spots or reticulations in black, browns and yellows. Adult female fruit flies lay eggs in living, healthy plant tissue and the developing maggots feed in a wide variety of plant parts, depending on the species. Some form galls on stems and roots; a few tunnel in leaves; others develop in the fruits, seeds and ovaries, especially in plants of the huge aster family. Those that attack fruits and vegetables can be severe agricultural pests. The Tephritidae is among the most economically important fly families, not only because of its destruction of useful plants, but also because many species are extensively used in the biological control of weeds. Adults are frequently seen on their host plants, walking around and raising and lowering their patterned wings. The Family Tephritidae is a cosmopolitan family of about 4350 known species, in 481 genera;

Family: Psilidae (Rust Flies)

Members of the Psilidae are small to medium-sized flies (Nearctic species are 3 to 8 mm long), rather slender and with only sparse bristles. The body colour ranges from yellow and red to brown or black; the wings are usually clear, yellowish or smoky, sometimes with the crossveins or wingtip darkened. The head is circular or triangular in profile with the frons projecting anteriorly and the face below the antennae strongly sloped backwards. The compound eyes are variable in size, but the back of the head below them is somewhat swollen. The antenna ranges from short to rather long, the third segment (and sometimes also the first two) often elongate (*Loxocera*) and bearing a setulose arista on the basal half. Head bristles are few and variable, but there is always at least an inner and outer vertical bristle on each side; vibrissae are absent. The wing has a strong subcostal break well before the end of R_1 ; a clear strip in the wing membrane obliterates the end of Sc and reaches or crosses R_1 . The outer end of cell cup is squarely truncate and vein A_1 fails to reach the wing margin. The legs lack bristles, but there are longer setae on the tips of the

tibia. The underside of the femur of *Loxocera* species bears a pad of short dense setulae near the tip. Larvae feed in the roots and stems of many kinds of plants (recorded hosts include sedges, rushes and lupines); a few species are pests of crops. The most injurious species is *Psila rosae* (Fabricius), the Carrot Rust Fly, which tunnels in the roots of carrots, parsnips and celery. Larvae also live under the damaged bark of trees. Adults rest on foliage, especially in the shade; some species are attracted to tree sap. The Family Psilidae is mainly Holarctic with a few species scattered in the southern hemisphere. It contains seven genera and about 200 species.

Superfamily: Ephydroidea

Family: Drosophilidae (Pomace Flies, Vinegar Flies, Lesser Fruit Flies)

Nearctic Pomace Flies are small to medium-sized, 1 to 6 mm long; body colour varies from yellow to brown or black, and can be shiny or grey pruinose. There are frequently stripes or spots on the thorax and abdomen. The compound eyes usually are covered in a distinct micro-pubesence and are often bright red in life. The head has three orbital bristles; usually the back two curved rearward, the front one forward. The ocellar bristles vary from large to small, as do the postorbitals; the latter are convergent and are almost always present. There is one to several strong vibrissae. The antennal arista is normally plumose, although it can be bare or have reduced branching. The scutum usually has two postsutural dorsocentral bristles. The tibiae have apical and preapical dorsal bristles. The wing has both humeral and subcostal breaks of the costa; the end of the subcosta is usually vestigial. Crossveins r-m and dm-cu are always present; cells bm and dm either separated or joined. The larvae of pomace flies mostly eat yeasts and other microorganisms in fermenting organic matter. Adults live around garbage, compost, rotting fruits and vegetables, decomposing cacti, sap from tree wounds, fungi and dung. A few species can be annoying pests in markets, breweries, bakeries and canneries. Some are used as laboratory animals for genetic and physiological research because they are small, fecund and so easy to rear and maintain. Many species of *Scaptomyza* Hardy are leaf miners; larvae of *Cladochaeta* Coquillett are ectoparasites of cercopid nymphs; species of *Pseudiasata* Coquillett prey on mealybugs.

The family Drosophilidae comprise of about 60 genera and 3000 species worldwide many of them in the tropics. The family is dominated by the genus *Drosophila* Fallén, which has about 1600 described species worldwide. It is certainly the best known scientifically because of its wide use in research laboratories.

Family: Diastatidae (Diastatid Flies)

Diastatids are small flies, about 2.5 to 4.0 mm long, grey-brown, with patterned wings. The head is higher than long and the frons narrows from the vertex to the antennae. The vertical bristles are strong; the inner pair is often longer than the outer pair. The postocellar bristles converge and the ocellar bristles arise prominently behind the front ocellus. Two orbital bristles of unequal size curve backward and a third one points forward. The face is flat; the vibrissa is strong, lying

in front of a row of 5 to 7 subvibrissal setae. The compound eye is bare. The antenna has the second segment swollen above; the third segment points downward and bears an arista that ranges from almost bare to feathery. The scutum has short, depressed setae; two postsutural dorsocentral bristles are present. The scutellum is flat, lacks setulae, but bears two pairs of bristles. The wing is usually twice as long as wide; the anal lobe and alula are weak to absent. The costa is weakly, but distinctly spiny and has both humeral and subcostal breaks. It extends to the end of vein M_{1+2} at the wing tip, but is weak past the end of vein R_{4+5} . The subcosta is incomplete. Crossvein r-m is basal to the middle of cell dm and the crossvein dm-cu is about as long as the part of vein CuA_1 apical to dm-cu. Vein A_1 is weak and short. The wing is usually spotted with brown or has white spots on a brown background. The legs are slender; the front femur always has a comb of short stout setae on the lower front margin of the apical half. All tibiae have a dorsal bristle just before the tip. Adults are encountered around rich herbaceous vegetation in moist woodland and on the edges of peatlands and other wetlands. The males of some species wave their spotted and reflective wings during courtship displays. The biology of the immature stages is unknown. The Diastatidae contains about 40 described species in four genera worldwide. Examples are *Diastata eluta* and *D. Modesta*.
