Chapter

Typical Flies: Natural History, Lifestyle and Diversity of Diptera

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Abstract

The Order Diptera, comprising of two-winged or true flies, is one of the most commonly recognized and widespread insects all over the world. During their long evolutionary history, virtually every terrestrial and aquatic niche has been occupied by Diptera, thus making these one of the most successful groups of organisms on earth. The main purpose of this chapter is to provide modern, well-illustrated and easily interpretable information for economic importance, life histories, habits and habitats, lifestyles, diversity, identifying and studying, pharmaceutical and industrial applications, ecological and human services, pests and vectors of diseases, predators and herbivores, pollination and biological control agents, association with carcasses, forensic science, phylogeny and classification of Diptera. Without doubt, this fragment of book provides the basics for understanding diversity of a major order of insects and is the first such synopsis of its kind for scientists and public alike.

Keywords: flies, vectors, pests, ecosystem engineer, forensics

1. Introduction

The so-called true flies are one of the utmost important groups of insects in the order Diptera. The name Diptera, is derived from the Greek words '*di*' meaning two and '*ptera*' hereby meaning wings, which refers to the fact that true flies have only a single pair of wings (two wings). This is distinguishing character because other insects have either two pairs of wings or four wings. Diptera's ancestors also have four wings, but in dipteran insects, second pair of wings is evolved into halteres, which are modified balancer organs that give to insect an amazing amount of fine control while flying.

Many winged insects, such as the butterfly and whitefly, contain the word 'fly' in their names, but are not dipterans, and the name is strictly applicable only to members of Diptera. There is an accepted custom for writing the common names of insects, which have included the word 'fly'. When any name is for a group of insects other than Diptera, it is written as single word (mayfly, dragonfly, and stonefly). But, if an insect belongs to Diptera order and word 'fly' is included, the name is written as double words (horse fly, black fly, crane fly). Diptera is one of the largest insect orders and quite diverse with its numbers more than 125,000 species worldwide. Our world's score of more than 152,000 described species within more than 130 known families is based primarily on figures extracted from the 'BioSystematic Database of World Diptera' [1].

The close association of dipteran flies with humans has led them to be recognized as unpleasant and disturbing creatures, and certainly some flies are responsible for millions of illnesses and deaths among human populations. Yet flies are also among the key components in most ecosystems and known advantageous in many ways. Voluminous flies are of great economic importance because some bloodsuckers are serious pests of humans and other animals. These insects are key vectors of some diseases, although others are pests of cultivated plants. Flies are advantageous as well by operating as predators or parasites of certain insects, scavengers as well as pollinators of plants and killers of weeds harmful to persons. Often called maggots or grubs, dipterous larvae, are found in many habitats (in water, plant tissue and soil, animal matter and decaying plants, below stones or bark, pools of crude petroleum), whereas adults forage on plant or animal juices or other insects. Diptera falls into three big sets, Nematocera (flies with multi-segmented antennae such as crane flies, midges, gnats, mosquitoes), Brachycera (flies with stylate antennae, for instance, horse flies, robber flies, bee flies) and Cyclorrhapha (flies with aristate antennae, such like, flies that breed in vegetable or animal material, both living and dead) [2, 3].

2. General features

Dipteran insects are plentiful all over the sphere, in the tropics and subarctic, at oceanic level and on elevated peaks. These inhabit seashores to low-tide level, however, a small number move into deeper water and merely one or two midges are actually oceanic (*Pontomyia natans* Edwards in the Pacific). In contrast, wandering flies have been observed at much distant to marine. In general, flies vary in dimensions from robber flies more than 7 cm lengthy to midges of little more than 1 mm long. As a whole, the more-primitive flies (midges, mosquitoes, fungus gnats) are fragile insects and with delicate wings. The more-progressive flies (house flies, blow flies) are commonly bristly, thick and tough, and forceful fliers than gnats and midges.

Even though these have simply two wings, flies are among the greatest aerialists in the world of insects as they can fly forwards and backwards, turn at any place, hover, and even fly upside and down to land on a top boundary. Flies have the uppermost wing-beat rate than any of other animal. It may be as high as 1000 beats per second in case of some small midges. Generally, through the wing-beat frequency of a virgin female, male mosquitoes are attracted. Maggots of certain shore flies (family Ephydridae) live in uncommon habitations, which would destroy other insects. For instance, *Ephydra brucei* survives in warm geysers and springs wherever the water hotness go beyond 112°F. The petroleum fly *Helaeomyia petrolei* Coquillett

Figure 1.
Wetland ecosystem.

develops in ponds of crude oil; and brine fly *Ephydra cinera* Jones, may live in extraordinary concentrations of salt [4].

The arista in the antenna of higher flies is an air speed indicator and it permits an insect to sense precisely just how fast it is moving. As black fly pupae mature, they become inflated with air. The pupal skin pops open upon emergence, and the fully-grown fly inside a bubble of air floats to water surface and it never even acquires its feet wet. The little scuttle fly *Megaselia scalaris* (Loew) is actually an omnivore. It has been cultured on paint emulsions, decaying vegetation, shoe polish, human dead body kept in formalin and even lung tissue from living people. As Diptera comprises the most ecologically diverse order of insects, swamps (wetlands ecosystem) resembling to this one (**Figure 1**) inundated by water and dominated by plant life, are great places to find its members.

3. Diversity among Diptera

Diptera have successfully colonized all continents including Antarctica, and are diverse not only in species richness, but also in their structure, habitat exploitation, life habits and interactions with humankind [5].

Maximum of nourishing and buildup of biomass take place in the larval stages and adults Diptera generally take energy they require to supply their flight muscles. Among those flies that forage widely, their foods contain honeydew or nectar (Blephariceridae and Bombyliidae), vertebrate blood (Culicidae and Glossinidae), pollen (Nemestrinidae and Syrphidae), insect hemolymph (certain Ceratopogonidae) and other biological resources that are liquefied or can be suspended or dissolved in regurgitated fluid or saliva (Muscidae, Calliphoridae and Micropezidae). The grownups of several groups are predaceous (Asilidae, Empididae and some Scathophagidae), while those of a few Diptera (Oestridae and Deuterophlebiidae) that totally lack of mouthparts, do not take food and live only for a short period [6].

Larvae of most species can be considered aquatic for existence, they need moist to wet atmosphere inside living tissues of plants, within decaying organic matters, as parasitoids or parasites of animals, or else are in link with water bodies. Maximum of larvae are free-living and crawl, tunnel or swim vigorously in water (Culicidae, Chironomidae, Chaoboridae, Simuliidae), sediments (Tabanidae, Tipulidae, Ceratopogonidae, Psychodidae), wood (Axymyiidae, Tipulidae, some Syrphidae), fruits (Tephritidae, Chloropidae), or decomposing biological material (Muscidae, Ephydridae, Sphaeroceridae, Sarcophagidae), whereas other larvae dwell in the tissues of alive creatures (Oestridae, Acroceridae, Tachinidae, Pipunculidae) [7].

4. Prominence of Diptera

The utmost essential significance of flies is not based only on limited acquainted families that comprise mosquitoes, tsetse flies, houseflies and other annoyance insects, but rather in the huge numbers of unfamiliar species that are a vital component in food chains upon which much of life rests on. Flies are of considerable ecological importance and their abundance, worldwide distribution and habits combine to make them a nuisance to humans by landing on people or entering homes or businesses. Midges and gnats are common names for a large number of small, non-biting flies and an important part of aquatic food chains. Swarms or clouds of midges in the air are a collective nuisance. Face flies and sweat flies, gather

nearby the mouth, eyes and nose, and likewise suck pus and blood from sores and wounds. Such flies constantly move from one individual to the subsequent and in doing so, sometimes can transmit disease-causing pathogens [8].

The order of true flies contains more species with aquatic stages than any other insect group. Unlike all other invertebrate orders, dipterans contain many species that as adults are harmful or at least annoying to humans. At the top of the list are mosquitoes; however other harmful groups comprise horse flies, black flies, deer flies and biting midges. Various fully-grown dipterans transfer pathogens or parasitic diseases that can be fatal or devastating to persons, such as dengue, malaria, yellow fever, and West Nile virus. Furthermore, other flies (some midges) develop in such great numbers that they may cause allergic responses in persons or else block air conditioning items. Conversely, dipteran larvae are tremendously essential in aquatic food webs and specific groups are raised in hatcheries as fish diet, and several fully-grown dipterans are a vital food for dragonflies and birds such as swifts, swallows, flycatchers and phoebes [9].

In warm countries, eye gnats are an annoyance and although their larvae are plant feeders, the tiny active adults forage on physiological secretions, generally those around the eyes. Additionally, few flies cut the skin of vertebrates and nourish on their blood. Sand flies, mosquitoes, black flies, horse flies and biting midges have developed maxillae and blade like mandibles with piercing stylets. Such piercing organs are evolved only in females, which for egg production usage blood protein, whereas male dos not forage on blood [10].

Other flies groups have developed diverse devices for attaining blood meal. Stable flies, tsetse flies or biting house flies (*Stomoxys*), and some parasitic flies have evolved a tough drill like labium to substitute the soft sponge like mouth part. Both females and males have developed this labium and they forage on blood. A small number of flies correlated to the house fly have a spongy proboscis furnished with minor teeth for scratchy skin around sores and wounds to raise lymph and blood flow. Other insects (robber flies) have evolved piercing proboscis merely used against other insects.

Spread of disease that takes place by use of piercing organs such as a proboscis is reflected as mechanical transmission. In the blood, disease-producing organisms might be picked up by a fly introducing its proboscis into an infested individual. Then disease can be transferred by blood sucking fly, which injects its saliva into the wound of other persons when their skin is pierced. Without anticoagulant properties of saliva, blood sucking would be difficult as the minute hole drilled by proboscis would block with coagulated blood. When mouthparts are contaminated with blood that contains microorganisms, they can be injected together with saliva, into another person; this is termed as direct transmission of disease. One contagious disease caused by a bacterium found in wild rodents is tularemia that may be transferred in this way. Trappers who cut themselves while skinning animals can contract with the disease. The bacterium is also transmitted by deer fly (*Chrysops discalis*), Williston common in wooded trapper country.

In the Middle East and parts of Asia, surra is a disease of horses and camels caused by the protozoan *Trypanosoma evansi* and transmitted by horse flies. Trypanosomes are transferred by tsetse flies that cause sleeping sickness in humans and nagana in animals all over tropical Africa. These trypanosomes essentially pass a portion of their life cycle in the insect prior to they can contaminate a vertebrate host and this is an example of cyclic disease communication. The connection between two hosts, vertebrate and insect and parasitic disease organism is a result of evolutionary adaptation. On the other hand, it is not recognized whether the trypanosome originally has a fly parasite that speeded to humans and other

vertebrates or else whether it has a human parasite that became adapted to live in a biting fly [11].

Malaria is a cyclically transmitted significant disease and causal mediator of human malaria, *Plasmodium*, is a cellular protist that feeds in human blood on red blood cells. Its propagative cycles cause repeated attacks of illness. Sometimes sexual forms take place in blood of victims. When this form catches its mode into an appropriate blood sucking mosquito, a different phase of *Plasmodium* arises, making an organism to contaminate one more human host bitten by mosquito species. Further illnesses recognized to be transmitted cyclically comprise encephalitis, filariasis, yellow fever and other viral infections [12].

Some flies larvae are severe pests of agriculture, they forage on young and mature crop plants and check growth otherwise destroy them. Cultured crops, for the reason that they offer to pests with a nearly limitless nutrition resource inside a small space, may be destroyed by uncontrolled density of a pest. In contrast, wild food plants, for the reason that they are mixed and scattered with other varieties, do not generally offer much plentiful of food supply and therefore work as a check on population growth. Fruit flies may result a 20% damage of an oat crop and to the value of the lost oats might be added the price of control actions essential to protect the leftovers. Several crops, particularly ornamental shrubs and fruit trees are of an economic injury if to some extent spoiled by insect invasion, although the life of plant is not threatened. Fruit, although is eatable afterward injured by Mediterranean fruit flies, yet cannot be traded since a limited infected fruits can result in loss of an entire consignment. Larvae of leaf miners and gall midges reduce the saleable price of ornamental plants [8, 13, 14].

Brown white-tipped brown bee fly *Comptosia walkeri* Edwards (brown in color with golden hairs on body and wings having white stripe on tips) (**Figure 2**) and fly *Comptosia insignis* (Walker) are members of family Bombyliidae. These flies superficially resemble to bees owing to their bodies built stoutly that are shielded with hair and by bearing their long and thin proboscis. These together with their flight lifestyles have gotten them collective name of bee flies or humble flies. Adults may be seen frequently hovering over or resting on blossoms or areas of plain ground in sunlit localities. Adults of bee flies suckle on nectar from a widespread diversity of floras and can be key pollinators of plants. Even though a slight is recognized about

Figure 2.
Comptosia walkeri.

some species, bee flies larvae are thought to parasitize the larvae of other insects and may prey on egg-masses of locusts and grasshoppers [15].

Family Tephritidae comprises peach fruit fly *Bactrocera zonata* (Saunders) mainly pest on peach and other stone fruits; guava fruit fly *Bactrocera correcta* (Bezzi) common on guava, mango and citrus; oriental fruit fly *Bactrocera dorsalis* Hendel recorded on fruits and vegetables; and melon fly *Bactrocera cucurbitae* (Coquillett) that is a major nuisance of cucurbitaceous vegetables (**Figure 3**) [16–19]. Overall, the damage to fruits and vegetables caused by fruit flies results from adults oviposition in hosts and soft tissues of vegetative parts of certain plants, feeding by white legless maggots, and decomposition of hosts tissue by invading secondary microorganisms [20–23]. Integrated pest management (IPM) packages for fruit flies include, mechanical controlling by protective coverings on the host and the destruction of adults with baiting and male annihilation techniques, biological control with biopesticides and parasitoids, cultural control through field sanitation and resistant varieties, using selective pesticides for backup only, and post-harvest control by careful host selection and hot water immersion treatment [24–38].

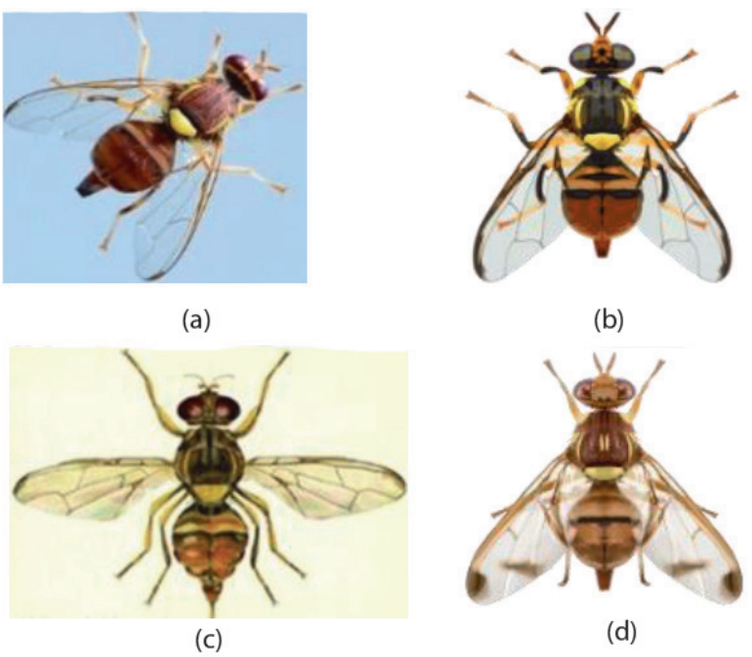

Figure 3.
(a) Bactrocera zonata, *(b)* Bactrocera dorsalis, *(c)* Bactrocera correcta, *(d)* Bactrocera cucurbitae.

Figure 4.
Musca domestica.

The house fly (*Musca domestica* Linnaeus) (**Figure 4**) can be dangerous because it moves from person to food, drinks, garbage, carrion or feces. It is possibly our most public adult fly and though this is a non-biting fly, it may be of significant prominence as a nuisance. In addition, it has a probable role for mechanical transmission of several sickness causing agents owing to its occurrence in fecal and decomposing organic matters. Through transferring of infective organisms from decomposing material or from infected people, house flies are agents in transmitting of typhoid, dysentery, cholera, summer diarrhea in children, and other intestinal virus and bacteria causing diseases.

The house fly is about 6–7 mm in length and females generally bigger than the males. The female may be differentiated from the male by means of comparatively broader space among the eyes (in males eyes mostly touch). The head of adult fly has reddish eyes; thorax bears four narrow black stripes, while abdomen is gray or yellowish with dark midline and irregular dark markings on the sides. The mouth parts of this fly are modified for lapping up of food material. The egg is about 1.2 mm in length, white colored and singly laid; however, eggs are stacked in small clusters. Every female fly may deposit up to 500 eggs in a number of groups containing 75–150 eggs in a period of 3–4 days. The legless maggot emerges from the egg in warm weather within eight to 20 hours. Early instars larvae are 3–9 mm long, typical creamy whitish in color, cylindrical, but tapering toward the head. The larva goes through three instars; a full-grown maggot is 7–12 mm long and has a greasy, cream-colored appearance. The pupal stage, about 8 mm long, is passed in a pupal case formed from the last larval skin which varies in color from yellow, red, brown, to black as the pupa ages. Pupae at 32–37°C, acquire their complete development in 2–6 days, but at about 14°C need 17–27 days. The evolving fly discharges from pupal case by the usage of a consecutively shrinking and swelling sac known as ptilinum, to breakdown through the case.

Generally, warm season situations are ideal for the development of house fly and in as little as 7–10 days, it can complete its life cycle. On the other hand, the life cycle may require up to 2 months under suboptimal conditions. In temperate regions, as many as 10–12 generations may occur annually, whereas in subtropical and tropical regions more than 20 generations can take place [39].

Face fly *Musca autumnalis* DeGeer is a serious pest of cattle though this is a non-biting fly. Adults come together in great numbers around the face of cattle and other big ungulates. This has been involved in the spread of 'pink-eye' between cattle and its occurrence in great numbers has been liable for indirect harms in production comprising reduced weight gains and milk production. The adults are at maximum vigorous from spring through fall.

5. Anatomy and physiology

Any member of the order Diptera has evolved a simplified structure and physiological diversity. Dipteran larvae can be differentiated from maximum of other insects by means of their absence of segmented thoracic legs. As a replacement for the customary jointed legs, several crowds have one or more couples of fleshy locomotory prolegs on abdomen and or thorax, each with curled or even hook-like spines. Fleshy tubercles arise in several species and help together in locomotory and sensory tasks. The larva head may be heavily sclerotized and exposed, as in midges, or else toughly condensed and only moderately proud (from time to time only with mouthparts expanded). The abdomen and thorax are generally fleshy, from time to time with dispersed sclerotized plates, and the whole body is usually long and

tubular, mean lengths are 2–25 mm, however can range 10 cm in several species. Always, wing pads are lacking in larvae, however existing in pupae.

Various larvae breathe through the skin and minute gills exist in certain taxa. Others dipterans get oxygen using spiracles and either lengthy or small breathing tubes from the atmosphere (as in mosquitoes). Limited groups remove oxygen from plant tissues. Certain true midges like blood worms (a type of true midge), which to some extent frequent anoxic habitations, have an invertebrate form of breathing pigment hemoglobin that supports in catching of oxygen molecules.

Adult dipterans vary in size from 1 to 12 mm; however, comparative giants of 25–60 mm long are identified wherein the later contain bigger crane flies. They have a single pair of membranous wings; hind wings are rudimentary and nonfunctional for flying whereas the bodies are long and tubular. In feeding adults, the mouthparts are modified to sharp tubes for penetrating flesh and sucking up liquids as in mosquitoes or adapted for consuming liquid food using either blunt pads for sponging up liquid. Although crane flies are from time to time called 'mosquito hawks', these do not consume mosquitoes, nor they bite human being.

6. Reproduction and life history

Entirely, Diptera have a complete metamorphosis (holometabolous), meaning that they go through four life stages, for instance, egg, larva, pupa and adult. The number of eggs laid by a female varies by species, from just a few eggs to thousands of them. Mom does not have any involvement in the care of its babies, so it lays eggs on a food supply where they hatch. Females place their eggs in clumps or singly, generally near water and from time to time attached to other things. Eggs have a tendency to last only for limited days with the exception of diapause eggs, which are used to avoid unfriendly temperatures or the shortage of water in environment. Larvae, which often look like worms, hatch from the eggs and after hatching, the larvae of maximum species traverse three to four instars (six to seven in black flies) prior to pupate on land or near bottom or at water surface. The larval stage lasts for somewhere from nearly 2 weeks to some months. These larvae may have 'false legs' called prolegs that look like the little legs seen on caterpillars. But, Diptera larvae lack any truly jointed legs. As larvae are always divergent morphologically from adults and moreover live in different habitats, flies basically spend two distinct lives and thus are capable to adjust environmental changes successfully. In several flies (robber flies), neither larval nor adult stage predominates, their larvae actively forage in soil and both sexes of adult flies in flight catch other insects. Among mosquitoes, black flies and correlated blood sucking flies, larvae have distinguishing structures and spend active lives under water, and the complex mating method of adults is followed by blood sucking and egg laying (in the case of females).

There are several flies in which one stage is predominant, for example, groups of adult midges (Chironomidae), are noticeable and bothersome, however adults midge live just long enough generally fewer than a day to mate and lay eggs. The maximum of life cycle by the larval stage is occupied under water. Larvae in appearance are wormlike and certain are adjusted to oxygen-poor conditions, for example, the 'blood worm' that lives in the sludge of standing waters, usages hemoglobin as a breathing pigment. Larvae of few midges live in silken tubes, either filtering minute organisms from water for food or preying upon other creatures. Certain midge larvae have developed an elaborate mutualism or symbiosis, using other aquatic creatures, for instance, certain midge larvae and *Nostoc* (a genus of blue-green algae) utilize excreta of each other.

At the opposite extreme are tsetse flies (*Glossina*) and three families of pupipara (females birth young ones) parasites (Nycteribiidae and Streblidae feed only on bats blood, and Hippoboscidae feed on the blood of mammals and birds). Within these families, single egg is formed at one time and it hatches internally. The larva is nourished and retained within a kind of womb, ejected out after this has matured and instantly forms a pupa. Hence, larvae of these flies have not an independent life. As pupa is immovable, the active life of fly is spent as an adult. Maximum of Streblidae and Hippoboscidae, and whole tsetse flies, bear wings and generally transfer to different hosts, however certain species of these families and entire Nycteribiidae, cannot fly and are frequently wingless. Wingless flies might be recognized as flies afterwards thorough morphological checkup only. The lifespan of an adult varies by species and may extend from a few hours to weeks or months. Even though a multivoltine life cycle is mostly prevailing, certain dipterans create one generation only in each year (univoltine) and might need many years to create a fresh generation in arctic and further cool atmospheres. The shorter generation periods illustrating this order allow dipterans to react rapidly to fresh diet or other resources and to recover quickly from critical circumstances like stream waves.

6.1 Adults

There are many different shapes of true flies and they are soft-bodied insects, most are fairly small (less than 1.5 cm long), but a few can be larger (up to 4 cm). The adult body colorations of different fruit fly species vary from black through various shades of brown to orange or yellow. **Adult** antennae are filiform, stylate or aristate, mouthparts suctorial (haustellate), mesothorax larger than pro or metathorax, one pair of wings (front), hind wings reduced (halteres) and tarsi 5-segmented. Adult fly appears from soft pupa and is lined with a colorless integument (skin), and have made perfectly (although not fully pigmented) bristles and hairs. The newly evolving adult sips air to swell its wings and body, and to power flow of blood through body. In more progressive flies of set Schizophora, in head, an expandable membranous sac ptilinum is used to help this procedure. The ptilinum shrinks away afterward it has done its job, but behind, it leaves ptilinal suture, which is a horseshoe-shaped furrow growing over and alongside antennal sockets and found in Schizophora only.

6.2 Eggs

Mostly, flies lay eggs that hatch into minute larvae afterward a few hours or some days. The eggs number put down by one female fluctuates from 1 to around 250. But, a large number of succeeding eggs batches can be laid. Green bottle fly (*Lucilia sericata* Meigen), in confinement has set almost 2000 eggs. But, the number total is perhaps less than 1000 in ordinary environment when energy and time are gone seeing for proper places for laying eggs. Sites for egg-laying, preferred by females instinctively, are closely linked to habitats of larvae. As many larvae of fly forage into soft organic maters, several females have established telescopic ovipositors, made from either last three otherwise four segments of abdomen. The female uses an ovipositor to press its eggs within a mass of rotting matter. House flies and blow flies thrust their eggs among membranes of meat otherwise into any suitable cavity in rotting organic matter. Small fruit fly (*Drosophila* vinegar fly) that lays eggs in decomposing fruits and fermenting matters as well have this kind of ovipositor, but, large fruit fly (Mediterranean fruit fly) that lays eggs in the rind of developing fruits, bears a harder ovipositor. An elaborate ovipositors set up in robber fly is used to thrust eggs into axils of grasses and interstices of flower heads,

and from time to time even into plant tissues, to protect and conceal them from drying. Once hatched, the larvae drop to the ground and burrow below the soil.

6.3 Larvae

The larvae of true flies look like thick segmented worms, but they have many different shapes. They do not have jointed legs, unlike beetle larvae. Some larvae have mouthparts and a distinct head, but most do not bear typical structures. Larvae of fly have single joint characteristic, wherein all have lack of jointed true thoracic legs. Several larvae of flies have 'false legs' (pseudopods or prolegs) related to those that care fleshy abdomen of caterpillars. Flies are greatly more adjustable than caterpillars in this respect, and around anybody segment can have prolegs. The prolegs aid larvae to push through soil or crawl into narrow spaces.

The evolutionary tendency among larvae of fly has been in the direction of structural simplification, so, usually, primitive flies larvae are extra structured than larvae of further importantly evolved flies that display better physiological adaptability. Most members of suborder Nematocera or Brachycera larvae bear a well-built head having antennae, complex mouthparts and palpi related to several adult insects. Frequently they are so structurally modified to their distinctive mode of life that these are not capable to adjust any other. It is particularly true among aquatic larvae such as mosquitoes and possibly reaches at extreme in larvae of mountain midge that live in roaring torrents and creep on immersed rocks. Segments of their body are furnished with suckers and clinging processes. The maggots of Cyclorrhapha have tiny external structure other than the posterior spiracles and black mouth hooks.

In comparison to very specialized larvae, nearly half species of flies have larvae called maggots. The maggots have missing the complex head capsule of primitive flies. Their sharp anterior ends comprise one or a couple of mouth hooks. The rounded posterior end has one couple of spiracles posteriorly (outer air holes), which look as black spots to the naked eye. Microscopically, spiracles are recognized as pores or a complex arrangement of slits, which are valuable in differentiating of species.

Even though maggots display structural homogeneity, they are dissimilar physiologically. Maximum of maggots feed upon rotting organic material, however in forensic studies; there are wide dissimilarities in the food likings of various flies. Larvae of gout fly of barley and frit fly of oat are maggots of flies that fit into plant-feeding family Chloropidae. The hessian fly of wheat is the destructive larva of *Mayetiola destructor* (Say) (gall midges) in nematoceran family Cecidomyiidae. Even though external structure of maximum nematoceran larvae is diverse, the structure of gall midges that live totally submerged in plant tissue, has developed in the direction of simplification. Gall midges fly larvae are known as well gall gnats for the reason that feeding larvae result in the development of disfiguring galls on stems or leaves and harm to several kinds of plants. So, they have developed physiological diversity and simplified structure concerning food floras as have maggots of further progressive flies.

The greatest well-known blow flies existing are sheep blow flies, essentially species in *Lucilia* genus. Maggots of *L. sericata*, forage on tiny deceased animals, and in garbage and abattoirs cans, oviposit in dirty wool around anus of sheep otherwise in pus oozing from wounds and scratches, wherein these are essential means of sheep strike illness. These maggots from time to time occur in soil adjacent to buildings in towns and their diet basis is not recognized. Eight 'waves' of worms have been well-known, and each wave assaults deceased animals in a severe series

as decay develops from newly deceased carcass through thoroughness and decomposition to mummification. Though several maggots only appear during a noticeably definite stage of animal decomposition, the greedy large maggots of various blow flies nourish on any animal material, comprising living tissues [40].

The number of instars or larval stages is six or seven in black flies (Simuliidae) and four in most other Nematocera. Alongside the second line of evolution of flies, Brachycera have from five to eight instars, while Cyclorrhapha maggots of the most advanced flies have only three instars. Three economically important free-living instars exist for tephritid fruit flies. The *Urophora jaceana* (Hering) and *Urophora cardui* (Linnaeus) have the first instar remaining in the egg and exits as a second instar. One or two species have no molts and from time to time molts arise earlier to the larva hatches from the egg. Muscidae, for instance, are organized in three groups according to whether they are monomorphic (pass the first two instars in the egg, have one free larval instar), dimorphic (pass the first instar in egg, have two free larval instars) or trimorphic (have three free larval instars). Monomorphic larvae are constantly predatory; however, dimorphic and trimorphic larvae feed first on decaying matter (saprophagous) and, on the other hand, they may or may not be predatory in their final instar [41].

Larval breathing is adjusted to the medium wherein larvae live. Even though limited parasitic larvae (Pipunculidae, parasite in Drosophilidae and froghoppers, internal parasite of scale insect) take oxygen by the skin and maximum dipterous larvae require tracheal system to allocate oxygen. Basically, tracheal system possibly is exteriorly opened on each body segment by paired spiracles. The soil occupiers, Scatopsidae and Bibionidae, hold this system, even though maximum families have retained spiracles only on thorax (one pair) and one at the abdomen tip. These are even sealed in several aquatic larvae (larvae of biting midges and luminous larvae of some fungus gnats). On the other hand, larvae of mosquitoes and many other water-living fly larvae repeatedly come to surface for renovation of their oxygen provisions. Certain larvae of flies pierce twigs of underwater plants to get oxygen made by photosynthesis activity. In Cyclorrhapha, maggots heavily depend on posterior spiracles complex. Pupae take breaths by prothoracic spiracles, which are from time to time furnished with long tubes extending outside the puparium or cocoon.

6.4 Pupae

The pupal stage of a true fly is enclosed within a hard capsule (skin). It may have some of its legs and body parts visible or it may be hidden inside a larval skin and just looks like a brown capsule. Dipteran pupae have non-functional mandibles (adecticous) and may have the appendages free from the body (exarate) or glued to the body (obtect). In exarate type, the pupa is concealed inside the hardened skin (puparium) of the last larval instar. The external structures of adult fly (antennae, eyes, legs, wings) are obviously noticeable in the pupa. However, the pupa, is not every time visible to the sight, it may be encircled either in a puparium that is a case formed by toughening of the larval skin or in a cocoon of extraneous matter (silk, soil or a mixture of the two). In flies of Stratiomyidae family and others, which have maggots like larvae (whole Cyclorrhapha), a puparium is formed. Many fly families sporadically form cocoons and cocoon has developed an adaptive tool, which delivers an extra safety to the pupa. Pupae of mosquitoes, black flies (Simuliidae) and limited aquatic midges swim vigorously. Several pupae that lie in wood or in soil have evolved spines in order to aid them for effort to have their way to the surface just before appearance of adult insects.

6.5 Wings

Adult flies are usually active during the day when it is warmer and they also sometimes detect the vibrations of wing beats. Adult flies have only one pair of wings on the mesothorax or second thoracic segment. The hind wings, modified into small club-like halteres behind the much larger forewings, have a knob or club and a stalk, which may be big and thick comparative to the size of fly. The halteres vibrate above and below in time with wings and in flight perform as gyroscopes (maintain or measure motion). If fly rolls, yaws or pitches in the course of flight, halteres maintain their original plane of movement, twist at their roots, where special nerve cells identify the twist and cause fly to accurate its flight attitude. The base of halteres is elastic and when these are stirred, a fly is capable to control its flying. As the halteres curve at the base, a fly can change flight direction or speed thus making them well controllable in comparison to various other flying insects.

The wings of flies have a well-defined pattern of veins; each has a characteristic location and name, and often has taxonomic significance. A small number of true flies have a reticulation (network of small veins), nearly resembling to various other insects, which are called flies (dragonflies, mayflies, dobsonflies) mistakenly. Primitive flies tend to have complex wing venation, whereas advanced ones have simplified and reduced venation. Some of the small midges (Sciaridae, Cecidomyiidae, Mycetophilidae) have also reduced wing venation. Reduction or losses of wings take place in several families, predominantly, which dwell windy dwellings (islands, mountains) or caves, or those are exterior parasites among feathers and furs.

6.6 Eyes

Most adult flies have large eyes, to help them see when they are flying. Flies use vision more than most insects do and like all insects, they use their sense of smell a lot. The eyes of most flies often lodge on much surface area of head, particularly in males, where eyes may well come across in the middle line (holoptic). With few exceptions, in female flies, the eyes do not normally meet (dichoptic). In certain families, notably both sexes of small acalyptrate flies and robber flies are dichoptic. Parasitic flies or those that living in sheltered dwellings can have very little eyes or none of any kind. Characteristically, on the other hand, compound eyes of flies comprise several facets, for instance, house fly in each eye has 4000 facets and some *Drosophila* sp., has 700 facets per eye that help them to see.

6.7 Mouthparts

Characteristically, flies have suctorial type of mouthparts and several bear large fleshy pads along with drainage canals called pseudotracheae for proficient uptake of liquid. Mouthparts of certain flies are modified for piercing and stabbing of other insects, for instance, predatory dance flies (Empididae) and robber flies (Asilidae). Mosquitoes and certain other ectoparasitic insects have modified mouthparts for penetrating into vertebrate host skin, and take out blood and other body fluids. In various families, rostrum (proboscis) is altered for lapping and or sponging. These flies live on nectar, honeydew or exudates of different plants and animals (alive or dead). In further families, proboscis is amended for piercing or cutting the tissues of hosts. Many of these flies are outer parasites (mosquitoes and deer flies) that feed on the blood of their vertebrate hosts, including humans, and most wild and domestic animals [42].

Many flies have maxillae, most have also mandibles and stretched blades that cover a furrow in labium and arranged as tubular channel for sucking liquids. In many females (mosquitoes, blood sucking flies), for drawing blood, mandibles act as piercing stylets. Mandibles have been lost relatively entirely early in fly evolution or became functionless and as a result families of blood sucking insects, which afterward evolved have to develop other methods of piercing the hosts. Stable flies and tsetse flies usage toughened labium, dance flies and robber flies practice hypopharynx, and Dolichopodidae (metal green flies having very large legs) crush their prey with especially evolved teeth by wrapping in spongy labella of labium. Many flies suck their diet, whereas with few exceptions have condensed mouthparts and probably do not forage at all as adults. Therefore, diet of flies might be liquid, otherwise solids, which may be dissolved by stomach juices and saliva. Flies as well bear a couple of labial palpi fitted with sensory cells, which act as organs to detect smell, taste and touch. The antennae and palpi are important for scrutinizing of probable diet sources and appropriate spots for laying eggs.

6.8 Antennae

Entirely, flies bear antennae and great antennal structural differences occur among related species and genera. Members of suborder Nematocera (crane flies, midges and gnats) have whip-like antennae with two basal segments (scape and pedicel) and apical flagellum of many similar segments. Altogether in other flies, accurately called Brachycera, flagellums are contracted into a compound third segment and have remnants of the terminal flagellar segments remaining as a bristle-like arista or a pencil-like style.

7. Ecology of Diptera

Diptera are such a diverse group that they can be found just about anywhere and these are most common in humid or moist environments, but can also be found in deserts, forests, mountains and even polar regions. They are also common in both fresh and saltwater environments such as lakes, ponds, streams, marshes and swamps. There is hardly any life-supporting medium in which dipterous larvae have not been observed. Species of Diptera can be gathered in wide range of habitats from most polluted to most pristine environments, from fast flowing water to stagnant water or from saline water to freshwater. Pupae and larvae are found among aquatic vegetation, organic debris, problematic habitats, sand, fine sediments, gravel, mud, cobbles or bedrock. They might be restricted to and sometimes closely associated with water surface, water column, any of aquatic zones, main water flow, benthic, littoral or interstitial and hygropetric zones. However, maggots are the utmost essential larvae, for the reason that they perform a crucial part in restructuring and breaking down organic material. The waste produces expelled by the larvae offer nutrients for molds, fungi and other types of plants. Additionally, bodies of larvae, pupae and a lot of adult flies are essential diet sources for higher animals. Cases in point are aquatic larvae of mosquitoes and midges that are basic diet for fish. Also, the terrestrial maggots of various flies have a part in nutrition chains. Meanwhile, a blow fly is able to lay one to two thousand eggs; their density would upsurge terribly if more than a few of them stay alive. Maximum of the larvae pass away owing to desiccation, malnutrition and sinking or are used up by birds. Adult flies are snapped up by small mammals, birds, toads and frogs. Martins, swifts and swallows consume huge numbers of flies that have been brought into the air by convection currents. So, their density is conserved at a persistent level.

Within more primitive families in suborder Nematocera, larvae of flies have well-built head capsules having mouthparts of mandibulate type. These arrangements are absent or reduced in more progressive Brachycera and Cyclorrhapha suborders wherein larvae are recognized as maggots, having worm-like bodies and a couple of mouth hooks only for nourishing. The abdomen, thorax and legs of adult flies differ from short to long and appearance of fly is well-designed along with decorative style. From time to time, bright color and pattern of several flies (blow flies) is metallic, on the other hand, most often fly is concealed with a good coating called dusting or tomentum. Numerous flies, principally those of more greatly evolved families, are bristly and the strongest bristles have an accurate location, mostly on thorax. The identification of bristles, their arrangement and the method established on them is known as chaetotaxy [43, 44].

8. Nutritional requirements of Diptera

Nutrition involves balance between feeding habits of larval and adult flies, and primary feeding occurs during the larval stage. Adult feeding serves to compensate the shortcomings of larval nourishment. Adult flies often drink upon fluids, but some feed on any liquid that has nutrients. They also can 'spit' onto dry food and then suck up the spit and some extra nourishment from the dry food, and thus infect human food. Certain female flies suck vertebrates blood, for instance from mammals to get protein they need for their eggs. A small number of adults are predators; they grasp other insects, crack them with their mouthparts and draw out their organs and fluids [45].

Generally pupae do not feed, and several flies do maximum of their nourishing as larvae and fly larvae often feed continuously during day and night. Certain feed on plants or eat fungi, but mainly upon fruits. Certain species are gathering collectors (feed on organic detritus), filtering collectors (feed on suspended diatoms and fine detritus filtered from water column), scrapers (use mandibles to scrape algae and fungi), shredders by chewing and boring (feed on leaf litter or living macrophytes) and predators prey on other invertebrates including their own species. Some place their eggs in leaves or stems and their larvae emit chemicals that make the plant to swell up into a gall. This defends the fly larva and provides to it a sufficient of nutrition to feed. Further species consume deceased animals and several feed on dung. Certain filter microscopic diet elements from freshwater (river, lake, stream). A single large group of flies in nature is parasitic, these deposit their eggs outside or inside of other insects and spiders, and their larvae nourish on inside of hosts even though host is still thriving. A limited species are vertebrate parasites, like birds and mammals and live under the skin or into wounds of their hosts. Several dipteran larvae live in aquatic, semi-aquatic or wet terrestrial atmospheres. They are normally found in soil, animal tissues or plant and in carrion or dung, where there is almost always a little risk of desiccation. Certain species are herbivores; however maximum forage on dead biological matter or parasitize other animals, particularly vertebrates, mollusks and many other arthropods.

At one extreme are nonbiting midges, with larvae that vigorously filter microorganisms from water. Correlating to nonbiting midges are biting midges, black flies and mosquitoes. Female adults in these families need supplementing diet in an insufficient larval food. Even though one set of eggs rarely is put deprived of a blood food, but blood is essential to develop a subsequent lot. Flies, which place one egg batch devoid of blood, are termed autogenous and those that cannot lay without

blood at all are anautogenous. One species may have both types, probably as a result of unstable populations otherwise races rising from usual selection. Such as far north, great densities of biting flies (horse flies, black flies, biting midges mosquitoes) arise for the period of small Arctic summer and there are noticeably inadequate amounts of warm-blooded animals to offer diet. If flies clip blood, they consume it; however, these still stay alive, if not availed.

The adults do not feed and most flies visit flowers, which provide water, nectar and pollen. Although the name *Drosophila* means 'lover of dew', this insect sucks water and any other obtainable fluid. Nectar from flowers contains carbohydrates and most adult flies use this syrupy liquid. Pollens are tougher to obtain for a sucking insect than blood, which is rich in protein and a vital source of this nutrient. Several hover flies love pollen grains among hardened portions of labella prior to swallow them and certain flies actively probe into flowers, covering their eyes and heads with pollen grains. Although their role in pollination is less well known than that of bees, flies are important pollinators of flowers. Some plants (spurges) are often covered with small flies of different families. Small flies also feed on honeydew from aphids or whiteflies. Flies forage on dung and fluid produces of either vegetable decay or animal. They get nutrients from garbage dumps and farmyard manure heaps. These dwellings as well harbor several larvae, which nourish either right on biological diet available or feed on other larvae as carnivorous. Yellow dung fly larvae and adults, is a familiar example that target on other insects coming to dung [35, 36, 46].

Adaptableness of flies is obvious on a widespread range of foods consumed by the larvae. Aside from parasites, the maximum specific feeders are those larvae, which live in plant tissues (leaf mining Agromyzidae, may be limited to group of plants or one plant species). Commonly, pests of horticulture and agriculture (cabbage root fly) are multipurpose species, nourishing on a diversity of wild type hosts and altering their foods while offered with intense plantings of marketable crops. Numerous carnivorous larvae of fly (asilids) most likely reside in soil and consume animal or vegetable material, whatsoever is accessible. Meanwhile adult robber flies (asilids), forage on various insects, their larval diet is recognized to be insufficient. Certain maggots, predominantly young insect, which forage on plant material for the duration of second and first instars, turn into carnivorous in the course of third instar, where maximum of development occurs.

Adult flies escape from predators with their alertness and speed. Likewise, several flies mimic stinging insects, for instance, bees or wasps, therefore predators will avoid them. Larvae habitually live in dwellings that are hard to reach by predators. Well-known predators of flies are shrews (eat larvae and pupae), rodents (pupae), moles (larvae and pupae), toads (mostly adult flies), frogs (mostly adult flies), birds, ants, wasps, other flies, spiders, ground beetles (larvae and pupae) and true bugs (larvae and pupae).

In many cases, only the adult females of biting flies under certain circumstances get blood diet, Culicidae family of mosquitoes, possibly spreads dengue, malaria, filariasis, encephalitis, yellow fever and other illnesses. Tabanidae (deer flies/ horse flies) can transmit loiasis, trypanosomiasis, tularemia and some other sicknesses. Simuliidae family of black flies feasibly spread onchocerciasis of human and leucocytozoon contaminations in poultry. Moth flies of Psychodidae can transmit leishmaniasis, sand fly fever and further diseases. Family Ceratopogonidae having punkies and no-see-ums are small and on the other hand vicious biters associated to transmit some protozoan, roundworms and virus pathogens in animals and humans. Muscidae family of house flies is among the utmost cosmopolitan than all other insects. Particular species have piercing mouthparts while some others are

only scavengers, and diseases such as cholera, yaws and dysentery can be transferred on their mouthparts and feet.

Larvae of herbivores flies forage on plant tissues, some gall midges (Cecidomyiidae) bring creation of plant galls, some are parasites, predators or scavengers and this family primarily comprises the Hessian fly *Mayetiola destructor* Say. Numerous species of family Tephritidae (fruit flies) are agricultural pests, such as the apple maggot *Rhagoletis pomonella* (Walsh). Most larvae of family Agromyzidae are leaf miners, some are stem and seed borers, and many Anthomyiidae species are seed otherwise root maggots.

Scavenger larvae nourish in garbage, carrion, dung otherwise further biological material, pomace flies (Drosophilidae) larvae forage on rotting fruit, crane flies (Tipulidae) live in mud or soil, larvae of blow flies (Calliphoridae) nourish on carrion or garbage and include screwworm *Cochliomyia hominivorax* (Coquerel), midges (Chironomidae) aquatic larvae generally breath in mud and forage on biological material, and larvae of flesh flies (Sarcophagidae) usually nourish on carrion, but certain species can be source of human myiasis.

Predatory larvae or adults predate on other insects as prey and specific flies produce predatory maggots that feed on other maggots. The predatory maggots of *Chrysomya rufifacies* (Macquart) (bluebottle) are covered with spiny protrusions which deter other predators. Families such as Asilidae (robber flies) are wide-ranging predators of other insects, Bombyliidae (bee flies) has predatory larvae and adults mimic to bees, Syrphidae (flower flies) (**Figure 5**) have larvae that are aphid predators and maximum adults mimic wasps or bees, and Empididae (dance flies) adults are also predatory. Parasitic larvae are parasitoids or parasites of insects and animals. Families like Tachinidae have several species that are important biocontrol agents and parasitoids of other insects, Hippoboscidae (louse flies) adults are blood-feeding ectoparasites of mammals and birds, larvae of Sciomyzidae (marsh flies) parasitize snails and slugs, and Oestridae (warble flies and bot flies) larvae are endoparasites of mammals as well as humans [47].

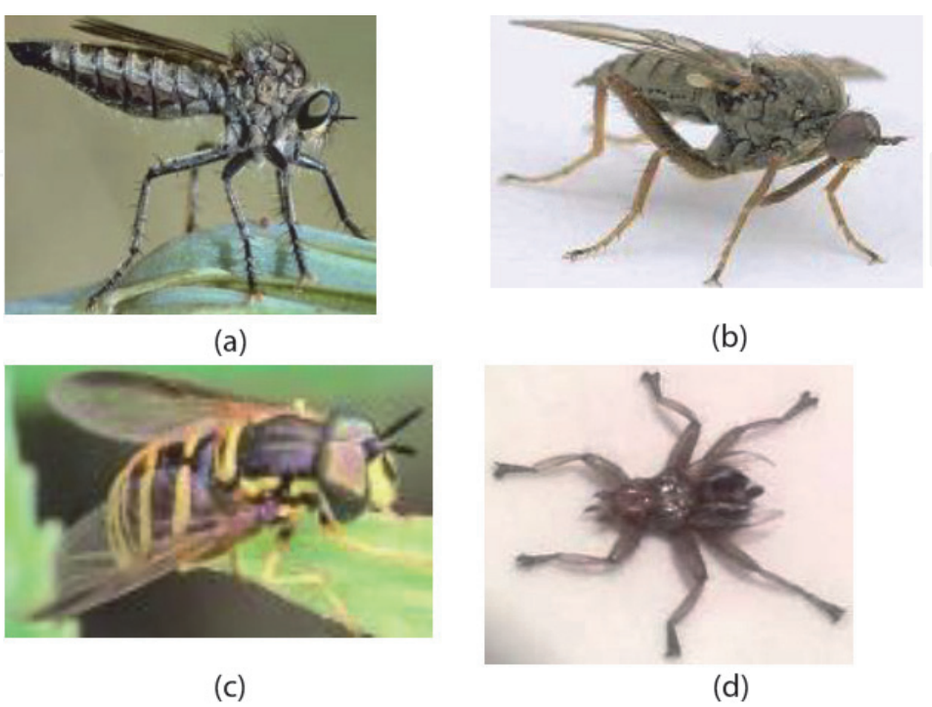

Figure 5.
(a) Robber fly, (b) Dance fly, (c) Flower fly, (d) Louse fly.

9. Roles in the ecosystem

The prime advantage of flies originates from the parasitic species. They invade grasshoppers, caterpillars and other insects that damage to food plants. Certain flies are also important pollinators and aid to pollinate plants that are grown. Flies are likewise essential food basis for other animals that are valuable such as fish. Many fly larvae are part of the natural clean-up squad, helping to get rid of dung and dead animals.

9.1 Decomposition: fly life cycle and development times

Marine Diptera, which perform decomposers function are land-dwelling muscoid flies, for instance, in aquatic habitations, Calliphoridae are under-represented mainly when a carcass is fully underwater. Corpses floating on surface of water and alongside shorelines, deal a terrestrial-aquatic boundary, which is expected to comprise dipteran agents of both surroundings. Certain ephydrids of shore-inhabiting devour minor carcasses of animals on seashores, suggestive of their legal prospective to as well practice bigger carcasses. Forensic circumstances in water linking to a deceased person normally feature presence of chironomids, their abundance, diversity, ubiquity and species-specific appearances, which make to Chironomidae possibly beneficial in criminal inquiries. Adhoc examples to utilizes marine Diptera in legal inquiries have been recognized. Exuviae of black fly *Prosimulium fuscum* (Syme & Davies) (**Figure 6**) pupae found on a submerged case helped to convict a murderer by countering his purported timeline of events [48].

Forensic entomology creates use of information resulting from either the series of arthropods on animal carcasses or human corpses or temperature-dependent development of insects (principally flies) to appraise the time gone since passing away or postmortem interval (PMI) or estimate of the time between death and corpse detection. Flies are the most significant organisms for forensic study and especially valuable in determining the age of corpse from duration of a few hours to a few years [49].

The occurrence of insects within any carcass is a serious sign toward guessing death time of bodies deceased for lengthier time periods. Since, flies quickly find out a body and their times of growth are foreseeable during specific ecological circumstances, so death time may be determined by calculating back days from the state of fly's growth existing on carcass.

Figure 6.
Black fly.

Fly species	Egg	First instar	Second instar	Third instar	Pre-pupa	Pupa	Total time (days)
Hydrotaea rostrata	48	60	60	36	144	324	28
Chrysomya rufifacies	24	36	36	72	72	168	17
Calliphora augur	no eggs	24	24	60	96	336	23
Calliphora stygia	24	48	24	48	96	324	23
Lucilia cuprina	26	33	33	24	114	324	23
Lucilia sericata	21	31	26	50	118	240	20

Table 1.
An average approximate development times (in hours) of some specific fly species at 20°C.

Blow flies (family Calliphoridae) are metallic blue, green or black in color, noisy in flight and resemble to the housefly. A female of blowfly at one time lays up to 300 eggs and with many females visiting any corpse, number of maggots may be immense. For instance, on a 156 g piece of meat, 48,562 maggots are initiated after 24 hours exposure. On the other hand, since this has been inadequate food to withstand them, only 231 flies lastly emerged. In hot weather, helpful to fly growth, maggots can devour 60% of a human body in less than a week.

The growth times of fly vary depending on the species and the temperature, but generalized life cycle typically takes 3–4 weeks depending on the species. Eggs are found in clusters of up to 300 and time takes 1 day from laying to hatching. Initially, first instar larva feeds on fluid oozed from body then migrates into body and takes 1 day from hatching to first molt. Larva of second instar travels around in maggot mass and from first molt to second molt takes 1 day. Larva in third instar moves still in mass, significantly increases in dimension and takes 2 days from second molt to pre-pupa. Pre-pupa drifts away from the corpse for seeking an appropriate pupation location (commonly in soil), does not forage, converts into pupa and takes 4 days from pre-pupa to pupa. Pupa exist within puparium, does not feed and transformation from pupa to adult fly emergence takes 10 days. Upon emergence from pupa, adults fly mate, feed on protein from body fluids, and lay eggs on corpse and emergence to egg laying takes 2 days [50, 51]. The life table (**Table 1**), shows an estimated development times (in hours) at 20°C of certain fly species.

10. Phenology

A characteristic life-cycle of dipteran follows a short-term egg stage (generally days or on occasion greatly longer), larval and pupal phases of variable length, and an adult stage lasting for a few to many hours or days. The period of larvula is shortest, while the last larval stage that is key feeding form is much lengthier. Totally, larval instars share an identical habitat, however various Chironomidae make sure to have planktonic larvulae and benthic later-instars. A lot of marine Diptera is univoltine categorized by quick development. In cyclical system with cold season, immature insects generally in an initial instar, diapause till environments are satisfactory. Postdiapause development regularly initiates with increasing spring hotness, even though algal accessibility and photoperiod may be associated. Period after egg-hatch to adult beginning differs among and occasionally contained by species, such as does presence of further generations (bivoltine to multivoltine).

Habitually, tropical marine insects constantly are newcomer and have shortage of synchronized cohorts. In short-lived, summer-dry system, certain larvae of flies diapause in hyporheic sediments till surface movement proceeds.

Non-feeding and shortened adult life is characterized in Deuterophlebiidae, Nymphomyiidae and many Chironomidae. Deuterophlebiids have the shortest adult lifespan than any Diptera, with females living for a few hours and males possibly 30–45 min. A short-lived, and nonfeeding imaginal phase would be adaptive anywhere larvae get means for gamete making or where ecological conditions unfavorably affect adult persistence [52].

11. Life of Diptera

Most flies remain active throughout the year and many of them live less than a year. Many fly species survive the winter only as eggs. Others survive as pupae and a few survive as larvae or adults. Like all insects, they do not truly hibernate, but enter a state of diapause, which slows down their development and appetite, until temperatures rise and they become active again. Unless they hibernate, adult flies do not usually live very long, often only a month or two and sometimes just few days or weeks. Flies usually spend most of their lives as a larva or a pupa, and mostly spend the winter as adults in cracks and openings, and become active in spring. Flies are eaten by many predators, so very few of them live as long as they can.

12. Classification of Diptera

Diptera has worldwide distribution, diverse habitats and diets in both larvae as well as adults, while sizes range 1 mm–7.5 cm. Among differentiating taxonomic structures, wings are utmost distinct feature of Diptera, and these comprise a couple of functional front wings and condensed rear wings termed as halteres that help as balancing organs. With the exception of male scale insects, Diptera only have hind wings adapted into halteres. The thorax contains a complete mesothorax occupied with muscles that operate to forewings. The single couple of wings as well differentiate to Diptera from other insects so-called flies (dragonflies, caddisflies), whereas the posterior halteres isolate Diptera from other insects having single pair of wings (certain beetles and mayflies).

Separation of Diptera into suborders is established on wing venation and structure of antennae. Additional key features are chaetotaxy and arrangement of strong bristles in several fixed locations, and given specific or group names. Split-up of Diptera into families is based on habits (feeding), and habitats of adults and larvae. Species and genera are differentiated by details of head structure and profile of head, degree of separation and shape of eyes, and legs shape and proportions of segments. Abdominal shape generally defines distinctive appearance of a genus, however it is hard to express because the shape differs as the insect is starving, well fed or gravid (viviparous flies, for instance, tsetse fly) [53].

Diptera order is traditionally divided into two suborders distinguished by the differences in antennae, Nematocera (flies with multi-segmented antennae) and Brachycera (flies with stylate antennae) having about 110 families divided between them although one suborder Cyclorrhapha is non-monophyletic (flies with aristate antennae) [54].

The Nematocera species are recognized by their elongated bodies and many-segmented, often feathery antennae as represented by mosquitoes and crane flies.

The Brachycera have rounder bodies and much shorter antennae. The Nematocera comprises commonly delicate and small insects having lengthy antennae such as crane-flies, mosquitoes, midges and their relatives. The Brachycera contains more robust and compact flies with small antennae [55].

In older classifications of Brachycera, two Divisions have been recognized; Cyclorrhapha and Orthorrhapha. Orthorrhapha contains brachyceran flies devising obtect simple pupae, for instance, robber flies and horse flies, and Cyclorrhapha comprises brachyceran flies having enclosed pupae within tough puparium. Cyclorrhapha is additionally separated in two sets built on absence or presence of ptilinum and fissure linked to head. Ptilinum is an eversible pouch above antennae base used during emergence of adult fly to push on and open anterior end of puparium. The Aschiza has an absence of ptilinum and it though exists in Schizophora.

Nematocera in general are soft-bodied and slender flies having long antennae containing of several segments alike, palpi of many segments noticeably often drooping, and wings bear numerous longitudinal veins, however in the middle of wing generally lacking the conspicuous discal cell. When present, the anal cell is broadly exposed. Insects in Brachycera are generally fairly big flies, of stout body, antennae short, however occasionally showing traces of more than three segments, wings generally with a very thorough venation and with a discal cell, and palpi neither more than two-segmented nor conspicuously drooping. Cyclorrhapha includes the most highly specialized Diptera, mostly of short and stout build, with short antennae and many bristles. In recent decades by a suite of workers, the customary assemblages of Diptera have been analytically revised within a cladistic framework starting with the great dipterist Willi Hennig. Consent has emerged that several of traditional categories such as Orthorrhapha, Aschiza and Nematocera are not natural sets (they are paraphyletic). In other arguments these categories contain a group of basal lineages from that of other (monophyletic) categories (Brachycera, Cyclorrhapha and Schizophora) stand up. Recently, efforts to frame a monophyletic classification of Diptera have achieved pace, however to date, no overarching consensus has been gotten [56–58].

Order Diptera all together is a group of familiar insects that has traditionally been divided into three suborders [59–62]:-

12.1 Suborder Nematocera

Antennae contain flagellum, pedicel and scape having many segments alike; maxillary palpi bear in excess of three segments, frequently pendulous; anal cell open in wing; larvae generally with distinct head; mandibles opposed horizontally.

Family Tipulidae (crane flies or daddy long legs): Body, legs, wings elongated; slow-flying; larvae within soil (leather jackets), rotten wood, mud, moss, marine, fresh water, seaside.

Family Mycetophilidae (fungus gnats): Delicate, slim; dip in wet shaded dwellings, between rotting foliage.

Family Sciaridae (dark-winged fungus gnats): Related to fungus gnats, however extra dense, more frequently indoors.

Family Bibionidae (march flies): Solid, well-armored flies; spurs on legs strong; frequently plentiful over spring blossoms; larvae found within soil, on occasion tangled in a mass close to plant roots.

Family Scatopsidae (minute black scavenger flies): Analogous to march flies, more frequently indoors.

Family Cecidomyiidae (gall midges): Minute flies rarely seen as adults; larvae shapeless, tunnel in plant tissues, form plant galls, collapse foliage, stalks, roots; certain horticulture and agriculture pests.

Family Psychodidae (moth flies): Minute, wings hairy; frequently visible alone in kitchens, windows over sinks; larvae generally aquatic; several larvae plentiful in dirt sedimentation containers.

Family Phlebotomidae (sand flies): Thoroughly interrelated to Psychodidae; female adults blood sucker, transmit intestinal and dermal leishmaniasis, sand fly fever.

Family Ceratopogonidae (biting midges): Minute, usually wings spotted (*Culicoides*); female adults annoying by bite, blood sucker, transmit certain parasitic worms; *Forcipomyia* blood sucker of insects.

Family Chironomidae (nonbiting midges): Correlated to biting midges, however females not blood sucker; larvae marine; essential for fish food; adults fly close to water.

Family Simuliidae (black flies, buffalo gnats): Minute, humpbacked, antennae short; females blood sucker, transfer parasitic worms causing 'river blindness'; under skin form nodules; aquatic larvae, fastened to stones, freshwater crustaceans or underwater vegetation, filter feeders.

Family Culicidae (mosquitoes): Elongated; small; prominent proboscis; long palpi; recognized best through scaly wings; various females blood sucker, transport human diseases (Culicini transmit filariasis, yellow fever, viral encephalitis, dengue; Anophelini transfer malaria); aquatic larvae and pupae.

12.2 Suborder Brachycera

Antennae flagellum always mostly joined to a compound third segment, left over diminutive segments practice a bristle-like or stumpy style arista; wing anal cell narrowed, nearly usually closed on or earlier to wing border; palpi rarely have more than three segments, usually one or two, detained frontward (porrect); larvae head usually well-defined, mandibles travel parallel or vertically, may not be opposed; through a rectangular slit adults escape from pupa (Orthorrhapha).

Family Stratiomyidae (soldier flies): Colorful flies, found relaxing with wings closed on vegetation; males occasionally in air dance; sometimes larvae extended, active, carnivorous (*Stratiomys*), aquatic; others in decomposing foliage (*Hermetia*).

Family Rhagionidae (snipe flies): Unremarkable, relax on vegetation usually; certain females (*Symphoromyia*) blood sucker; maximum larvae in soil otherwise in water (*Atherix* females make egg-laying flights); certain form pits in soil, such as ant lions (*Vermileo*).

Family Pantophthalmidae (timber flies): Big, outmoded flies, found currently only in South American tropical forests; wood-boring larval grubs from time to time injury profitable wood.

Family Tabanidae (deer flies, horse flies): Short flies having large heads, eyes colored brilliantly; certain females (*Tabanus*, *Chrysops*, *Haematopota*) blood sucker, pests of livestock; several primitive genera only feed on flowers; larvae in wet soil or mud, either carnivorous (*Haematopota*, *Tabanus*) or vegetarian (*Chrysops*).

Family Asilidae (robber flies): Adults in flight clip other insects, suck blood; vary in sizes as of a few mm to 8 cm (lengthiest than other flies); distinctive 'moustache' of hairs possibly defends eyes from fly's victim damage; larvae in wood or soil; feed on several diet.

Family Bombyliidae (bee flies): Scaly, hairy; resemble to bees superficially, in similar way hover over flowers; often patterned brightly, by rubbing scales pattern

ruined; in wasp and bee nests larvae scavenger otherwise parasitic (tsetse pupae, locust egg pods).

Family Scenopinidae (window flies): Black tiny flies, fond on indoor windows; larvae develop in carpets, nourish on clothes moth and flea larvae; usual habitation, nests of birds or related dry debris.

Family Therevidae (stiletto flies): Adults look like Asilidae, however not predacious; larvae elongated like Scenopinidae, worm-like, carnivorous however from time to time damage to plant roots.

Family Nemestrinidae (Tangle-veined flies): Somewhat similar to Bombyliidae; larvae parasitic on locusts, grasshoppers, beetles; noteworthy for attractive hovering pattern.

Family Acroceridae (balloon flies): Fantastic; tiny head; small thorax; swollen abdomen; larvae parasitic on spiders.

Family Empididae (dance flies): Adults take in insects blood, as well forage on flowers; *Hilara* projectiles above water, clasps minuet insects; larvae live in several habitations (decomposing vegetation, freshwater and marine dirt, flowing fluid from plants, fungi).

Family Dolichopodidae (long-legged flies): Minute, bristly, metallic flies; huge quantities assemble on foliage in misty locations; predacious on other insects; larvae similar to Empididae, lengthened, with slight outward head arrangement, identical habitations.

12.3 Suborder Brachycera-Cyclorrhapha

Generally condensed to Cyclorrhapha; typically make pupa within latter larval casing by way of a puparium; fly adults push off a rounded lid, therefore title as Cyclorrhapha; maximum families (Schizophora) have ptilinum (membranous pouch within head) that arises from horseshoe-shaped ptilinal suture (classifies Schizophora adults) over antennae, is puffed out and in to aid fly for escaping from puparium otherwise dust or to swell body of fly; ptilinum wastes and ptilinal suture leftovers only; individuals of minor group Aschiza, without ptilinal suture, are known primarily by their wing venation.

Series Aschiza: Do not possess a ptilinum, lack the prominent ptilinal suture on the face and have a puparium with a circular emergence opening, but not precisely ellipsoid.

Family Lonchopteridae (pointed-winged flies): Less well-known; famous for parthenogenesis; limited species globally; occasionally plentiful.

Family Phoridae (coffin flies): Minute flies, occasionally frequent indoors; larvae living in several biological fragments attractive with protein otherwise nitrogenous decaying produces; forage in nests of bees, wasps, termites, ants; breeding in carrion; several adults wingless or with small wings (brachypterous).

Family Pipunculidae (big-headed flies): Minute flies; head sphere-shaped; prominent for clear-cut hovering; larvae parasitic on Homoptera.

Family Platypezidae (flat-footed flies): Slight flies; legs peculiar; seen rarely; in wood fires smoke perform to dance; larvae living within fungi.

Family Syrphidae (hover flies): In wing vena spuria goes among third and fourth veins; aware in all places; fly above flowers, relax over foliage; certain larvae marine (rat-tailed' maggots); several species larvae forage on aphids living on plant leaves; stems.

Family Conopidae (thick-headed flies): Wasp like flies; larvae parasitic on wasps and bees; may possibly be an isolated evolutionary line.

Series Schizophora: Entirely flies in head have ptilinal suture, larvae without exterior head structure, through cuticle mouth hooks evident, one pair of

prothoracic spiracles; one pair of posterior spiracles both have either a mass of small pores or three slits, larvae called maggots with hind end truncate; fore end pointed, both ends fleshy and blunt, with bulges; tracts of spines termed grubs.

Section Acalyptrata: Small soft-bodied flies; thoracic squamae (calypters which link base of wing to thorax) evanescent or small; key families established well; location of genera unclear; families may be gathered in relation to larvae diet likings.

Flies breeding in vegetable compost and dung:

Family Lauxaniidae (lauxaniid flies): Possibly, look to mimic other insects, feasibly leafhoppers; larvae live in decomposing plant material.

Family Helomyzidae (helomyzid flies): Alike to Lauxaniidae; larvae nourish on rotting animal and plant materials; most widespread of Acalyptrata.

Family Dryomyzidae (dryomyzid flies): Identical to Lauxaniidae, however have broader variety of diet, comprising fungi; yellow flies generally visible in winter.

Family Chyromyiidae (yellow flies): Length 1 or 2 mm; breed in mammal burrows, bird nests debris, cellars, caves; singly visible on indoor windows.

Family Celyphidae (beetle flies): Scutellum extremely expanded till it conceals wings and abdomen while at relaxation; dung breeding.

Family Mormotomyiidae (terrible hairy fly): Comprises single African species, wingless; appearance similar to spider; identified only from single area in Kenya; breeds in bat excrement.

Family Coelopidae (kelp flies, seaweed flies): Breed in wrack (decaying piles of seaweed held on seashores) primarily in moderate states; various species adults appealed by trichloroethylene; pests occasionally.

Flies breeding in animal refuse, dung, carrion:

Family Sepsidae (black scavenger flies, ensign flies): Minute, roundhead, black flies; occasionally spots at wing tips; can breed to invasion level in sewage sludge.

Family Piophilidae (cheese skippers): Larvae live in ham, cheese, dried fruits, cured meats, conserved pelts and skins; natural habitation is preserving carrion; named 'skippers' for the reason that larvae travel together by skipping and crawling (gripping tip of abdomen with mouth hooks and flipping body relatively through a long distance).

Family Micropezidae (stilt-legged flies): Big, tall-legged flies; patterned conspicuously blue-black wings; enormous in tropics.

Family Sphaeroceridae (small dung flies): Minute, black-brown flies; hind legs first tarsal segments inflated; plentiful all over world in dung like resources; on beaches certain members exist in seaweed; several wingless or short-winged species.

Family Sciomyzidae (marsh flies, snail-killing flies): Larvae aquatic, feed upon together dead and living snails; can be valued as controlling means for harmful snails.

Family Milichiidae (freeloader flies): Dung breeder; adults fasten to spiders and predacious insects and nourish on these; named 'insect jackals'; *Madiza glabra* from time to time plentiful indoors.

Family Carnidae (bird flies, filth flies): Scavenge within burrows and nests; *Carnus hemapterus* adults scavenge between feathers of birds, breakdown wings.

Family Neottiophilidae (nest flies): Nest-breeding; larvae suck blood of nestling birds; resemble to calliphorid larvae.

Family Thyreophoridae (cheese flies): Among the rarest of flies; larvae are in dead bodies of large animals.

Family Chamaemyiidae (silver flies, aphid flies): Larvae predatory; recognized as controlling means of aphids and other soft-bodied insects including mealybugs and scales.

Family Braulidae (bee louse): Wingless fly, *Braula caeca*, exists in beehives; larvae feed on pollen and wax; adults attach to bee, can beg nutritious saliva similar to other bee colony members.

Flies with plant-feeding larvae:

Family Ephydridae (shore flies): Temporary; wide-ranging larval habitations; not any matter inedible to larvae (carrion, sewage, excrement, urine, brine tar pools, hot springs, algae); carnivorous petroleum fly (*Psilopa petrolei*) exists in crude petroleum pools seepage predating on confined insects; several larvae nourish on aquatic and terrestrial plants.

Family Diopsidae (stalkeyed flies): Certain larvae live in rotting plant matter, some mine in living vegetation.

Family Chloropidae (frit flies): Peak vital plant feeders; comprises pests of cereal and other crops.

Family Opomyzidae (opomyzid flies): Small, slender, yellow, brown or black colored flies; larvae live in stems of grasses including cereals.

Family Geomyzidae (geomyzid flies): Slightly slender; grayish or yellow color; seeing like pomace flies.

Family Psilidae (rust flies): Yellow to reddish, brown or black in color; head spherical; face often slanted backward; antennal third segment clearly elongated; carrot fly *Psila rosae* agricultural pest.

Family Agromyzidae (leaf miners): Larvae nourish in leaves parenchymatous tissue, reduce epidermis transparent and create either blotch mines or serpentine; deface decorative plants and shrubs.

Flies with fruit-feeding larvae:

Family Trypetidae (large fruit flies): Produce galls in several flowers mainly Compositae; a lot of Trypetidae larvae nourish in living fruits and deteriorate these; global scattering; damage by a number of members [Mediterranean fruit fly *Ceratitis capitata* (Wiedemann) is quarantine pest of fruits worldwide].

Family Drosophilidae (small fruit flies): Larvae live in decaying and fermenting fruits or sweet matter; comprises *Drosophila melanogaster*, used in genetic studies.

A number of minor families have been made to put up genera closely related to both above families, wherein, Otitidae (Ortalidae) and Lonchaeidae are most noticeably distinct, while others such as Pallopteridae, Ulidiidae, Camillidae, Diastatidae and Phytalmidae are unresolved.

Section Calyptrata: Characterized by large squamae (calypters which link base of wing to thorax); Scatophagidae are transitional.

Family Scatophagidae (dung flies): Living nearby dung, other rotting things; several as well predacious as adults and larvae.

Family Muscidae (housefly and allies): Several species including housefly; certain larvae specially in third instar carnivorous; breed in dung or decomposing plant material; *Fannia* larvae 'lesser housefly' like matters dipped in urine; economically significant muscid larvae nourish on plant roots and stems; subfamily Anthomyiidae comprises dipteran plant pests; stable fly *Stomoxys* (both sexes have biting proboscis) can be positioned in an isolated family Stomoxyidae; tsetse fly *Glossina* restricted to Africa, occasionally located in the family Glossinidae, occurred in North America.

Family Calliphoridae (blow flies): Certain bristly flies having carrion-feeding maggots; blow flies *Calliphora* (bluebottles) larvae feed in dead meat; *Lucilia* (greenbottles) occasionally invade living flesh; *Cochliomyia*, *Callitroga* (screw-worms) are hazardous feeders in living tissue.

Family Cuterebrinae (robust bot flies): Side-shoot of above family Calliphoridae; larvae parasitic in rodents; one larva *Dermatobia hominis* (human bot fly) as well attacks man; eggs on occasion attached to mosquitoes and other biting flies and passed to their potential victim.

Family Oestridae (bots and warbles): Larvae living in nose, under skin and in other head openings of big mammals; contains cattle warble fly *Hypoderma bovis,* sheep nostril fly *Oestrus ovis* and other species.

Family Gasterophilinae (horse bots): Larvae living in stomachs of horses, rhinos, zebras and elephants, involved to intestinal lining; association with other bot flies uncertain; presently categorized with other bot flies.

Family Sarcophagidae (flesh flies): Big, black and gray flies; common nearby garbage holes; larval behaviors varied, found in dead or living animal material; several viviparous species.

Family Tachinidae (tachinid flies): Biologically essential in equilibrium of nature for the reason that larvae are parasites in woodlice, other insects, centipedes, spiders; employed in biological pests control.

Section Pupipara: Doubtful group, families can only be convergent in habit; lay living larvae; adults of both sexes exclusively feed on blood.

Family Hippoboscidae (louse flies): adults feed on blood of birds and mammals; several fly, certain have wings lost or reduced (sheep ked *Melophagus ovinus*).

Family Streblidae (bat flies): Distinctive rounded head; wings generally efficient however fly slightly; closely cling to host.

Family Nycteribiidae (wingless bat flies): Continuously wingless; weakened and de-sclerotized thorax; living completely on bats; hardly detectable as flies.

13. Damage caused by Diptera to cured fish

Some Diptera cause significant damage in many ways, generally during the larval stages. The feeding by larvae of Calliphoridae causes quantitative losses on moist fish. These injuries can be severe if circumstances are optimum for fly growth and under such conditions, i.e., if poorly or unsalted and salted fish are dried gradually for the reason that of rain or high humidity, weight harms of 10–30% by fly larvae may be caused. Disintegration of fish by fly invasion can cause quality damage and may lead to bigger danger of damage by mites and beetles. Significant weight losses because of fragmentation of fish during treating have been noted, however the involvement of blow fly injury to this has not been assessed separately. Thorough and heavy salting provides complete protection against blow fly larvae.

Most flies found on cured fish belong to the subfamilies Calliphoridae (blowflies, bluebottles, greenbottles, screw-worms including *Calliphora* sp., *Chrysomya albiceps* Wiedemann, *Chrysomya bezziana* Villeneuve, *C. chloropyga putoria* (Wiedemann), *C. megacephala* (Fabr.), *C. regalis* Desvoidy, *Lucilia cuprina* Wiedemann, and *L. sericata*) and Sarcophagidae. Flesh flies includes *Sarcophaga* sp., *S. nodosa* Engel, *S. tibialis* Macquart and *Wohlfahrtia* sp.), in Calliphoridae family. The most common of these are several species of Chrysomya; however, Lucilia, Calliphora, Wohlfahrtia and Sarcophaga have too been stated. Other families of flies infesting cured fish denoted in records are Phoridae (Megaselia), Muscidae (Musca, Atherigona and Ophyra), Piophilidae (Piophila), Ephydridae (Discomyza) and Milichidae (Leptometopa). Entirely, these flies are somewhat alike in general form, although they display a diversity of coloration and size, and their proof of identity needs specialist information [63].

The larvae of some species can cause myiasis in livestock or man i.e., they may infect external wounds or can be swallowed and carry on developing in the intestine

as parasites. Adult flies of many pest species are invited to decomposing material (such as rotting offal of fish) and dung, wherever they may breed and feed. They might thus spread pathogenic organisms when these lay eggs on fish.

14. Biting Diptera

Biting flies are two-winged external insects that feed actively on the blood of vertebrate hosts in the morning or evening and at night or day, and their biting is of a considerable nuisance. Their irritating bites could transmit pathogenic organisms that cause devastating loss of human and animal lives. The biting insects suck blood from humans and animals, and their biting is of a significant annoyance. More importantly, they are carriers for a number of organisms producing diseases and result in expiries on a huge scale. The most significant set of biting Diptera is mosquitos that have a slender and long body, and needle-shaped long piercing mouthparts. Others comprise phlebotomine sandflies, blackflies, tsetse flies, biting midges, stable flies and horseflies (tabanids), which normally have smaller biting mouthparts and additional robust bodies. The last three sets as vectors of human disease are of limited importance [64].

14.1 Mosquitoes (Culicidae)

Mosquitos diverge from other biting Diptera in having long needle-shaped mouthparts, a long slender body and long legs. The wings occasionally have noticeable outlines of scales. The adult insects measure between 2 and 12.5 mm in length. Certain species bite at night or in morning and evening, whereas others feed out of doors or during the day time indoors. There are several important genera of mosquitoes and key genera include *Culex, Aedes* and *Anopheles.*

Males of the numerous species do not suck blood but feed on plant juices. The females usually mate only once, but produce eggs at intervals throughout their life and so most female mosquitos require a blood-meal. The ingestion of a blood-meal and the coinciding eggs development take 2–3 days in tropics, however longer in temperate regions. The gravid females look for appropriate places to lay their eggs, afterwards which another blood-meal is taken and another batch of eggs is laid. This practice is repetitive till the mosquito perishes. The mosquito life cycle involves eggs that are laid mainly in water. In some species, eggs are laid signally, while in others, these are laid joined together in rafts. Dependent on the species, a female lays eggs between 30 and 300 at a time. Various species directly lay their eggs on water surface either singly (*Anopheles*) otherwise fixed jointly in floating rafts (*Culex*). Particular species (*Aedes*) lay their eggs just above the water link otherwise on wet mud and only when flooded with water these eggs hatch. If left dry, these can keep on viable for several weeks. Larvae (wigglers) hatch and feed on aquatic material, pupate (become tumblers) and eventually emerge as adults. Adult females may live for several months [65, 66].

Among the mosquitos there are two groups that suck human blood and may transmit disease. The anophelines; the genus *Anopheles* is best known for its role in transmitting of malaria, but in some areas it can also transmit filariasis. The culicines comprise the genera *Aedes,* vectors of dengue, yellow fever and other viral diseases and from time to time of filariasis; *Culex,* vectors of filariasis and various viral diseases; *Mansonia*, transmitter of *brugian filariasis*; and *Sabethes* and *Haemagogus*, spreaders of yellow fever in forests of Central and South America. Mosquitos *Aedes*, *Anopheles* and *Culex* may be differentiated from each one by way as presented in **Figures 8–12**. The best valuable features to distinguish anophelines from other

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mosquitos are size of palps that is equivalent to proboscis; whereas these generally at rest retain their abdomen and mouthparts in a straightforward stripe at an angle to relaxing place; the angle differs within species and in various circumstances it is nearly erect to surface. In south Asia, vector of malaria *Anopheles culicifacies* Giles, is an exemption by keeping body nearly equivalent to surface. As per its name proposes, this one superficially looks similar to mosquito *Culex*. A number of mosquitoes, including *Psorophora*, *Aedes*, *Mansonia*, *Culex* and *Anopheles* spp., are important parasites of domestic animals. When the blood-feeding females are present in large numbers, they cause stress to animals and produce severe anemia [67, 68].

14.1.1 Anopheles *mosquitos*

About 380 species of *Anopheles* mosquitoes occur around the world. Some 60 species are sufficiently attracted to humans to act as vectors of malaria. A number of *Anopheles* species are also vectors of lymphatic filariasis and viral diseases. Female and male adult mosquitoes may be distinguished from every one due to occurrence of antennae that is bushy in males than females. Genus *Anopheles* may be distinguish from whole others genera based on occurrence of clubbed palps within males, while non-clubbed in rest of species and lengthy palps in *Anopheles* female whereas small palps in all other females (**Figure 7**).

The most preferred breeding sites are pools, seepages, quiet places in slow-running streams, rice fields, leaf axils of certain epiphytic plants and puddles of rainwater, but not artificial containers, except in the case of *Anopheles stephensi* Liston (**Figure 8**). The eggs are elongated, about 1 mm in length, have a pair of

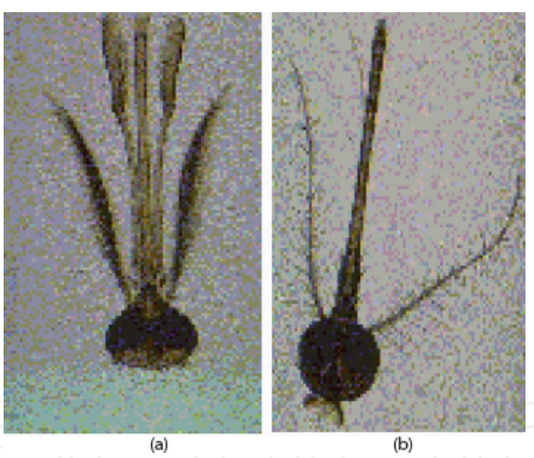

Figure 7.
(a) Male antenna, (b) Female antenna.

Figure 8.
Anopheles stephensi.

lateral floats and laid singly on the water surface where these float until hatching that occurs in 2–3 days. The larvae float in a horizontal position at the surface, where these feed on small organic particles. In the tropics, the duration of development from egg to adult is 11–13 days. Some species feed mostly on animals, while others feed almost entirely on humans. Mosquitos *Anopheles*, are active between sunset and sunrise, and there are variations also in their liking for biting outdoors or indoors. The anophelines, which come in houses to feed habitually rest for a few hours indoors after feeding, then can leave for outdoor protected resting sites like burrows, vegetations, crevices and cracks in ground, trees or in caves and undersides of bridges. On the other hand, they may stay for the whole period indoors required to digest blood-meal and produce eggs. Once the eggs are fully developed the gravid mosquitos leave their resting sites and try to find a suitable breeding habitat [69–72].

14.1.2 Culex mosquitos

About 550 species of *Culex* have been described, and most of them are from tropical and subtropical regions. Some species are important as vectors of bancroftian filariasis and arboviral diseases, such as Japanese encephalitis. Rafts of 100 or more eggs are laid on the water surfaces that remain afloat until hatching occurs 2–3 days later. These breed in a large variety of stagnant waters, ranging from artificial containers to large bodies of permanent water. The most common species, *Culex quinquefasciatus* Say (**Figure 9**), is a major nuisance and vector of bancroftian filariasis, which breeds especially in water polluted with organic material, such as refuse and excreta or rotting plants, pit latrines, blocked drains, canals and abandoned wells. It is markedly a home species, and females bite to people and animals all over the night outdoors and indoors. For the period of day, these are not active and frequently found hidden in dark corners of rooms, and as well rest outdoors in holes within trees and on vegetation areas. The vector of Japanese encephalitis, *Culex tritaeniorhynchus* Giles (**Figure 10**), prefers cleaner water and is most commonly found in irrigated rice fields and ditches [73].

14.1.3 Aedes mosquitos

Mosquitoes *Aedes* occur around the world and these can cause a severe biting annoyance to people and animals, both in cooler climates and in the tropics. In tropical countries, yellow fever mosquito, *Aedes aegypti* (**Figure 11**) is a key vector of yellow fever, dengue fever, dengue hemorrhagic fever and other viral diseases. A thoroughly related species, Asian tiger mosquito *Aedes albopictus* (Skuse),

Figure 9.
Culex quinquefasciatus.

Figure 10.
Culex tritaeniorhynchus.

Figure 11.
Aedes aegypti.

can spread dengue as well (**Figure 12**). In certain regions *Aedes* species also spread filariasis [74–77].

14.1.4 Mansonia mosquitos

It includes 15 species classified in subgenera *Mansonia* Blanchard and mosquitos are mostly found in marshy areas in tropical countries. These mosquitoes can be very alike to common mosquitoes in genus *Aedes*, however vary by having the last segment of abdomen much broad, rather than markedly narrower as in *Aedes*, and through having most of scales very broad on the top of wings, rather than long and narrow as these are on *Aedes*. These may as well be differentiated from several other mosquitos genera through having a tuft of bristles (post-spiracular bristles) on body plate instantly

Figure 12.
Aedes albopictus.

behind spiracle on the sideways of thorax. Some species are important as vectors of the helminthes that cause brugian filariasis. Their body, including the legs and wings, is covered with dark-brown and pale scales, giving it a rather dusty appearance, as if sprinkled with salt and pepper. The larvae of *Mansonia* species occur in permanent waters in association with aquatic plants that have roots used for attachment by the siphon to obtain oxygen for respiration from air cells. Mosquito *Mansonia titillans* (Walker) (**Figure 13**) is known to transmit various arboviruses, including Venezuelan equine encephalitis, while species *Mansonia dyari* Belkin, Heinemann and Page should be considered a potential vector of Rift Valley fever virus [78].

A number of control approaches are employed against every stage in the life cycle of mosquito. Difficulties exist with the whole forms of control options and their continuous applications are generally required to produce any effect. Different forms of natural control are currently being trialed with personal protection of human, and selecting and breeding of livestock species, which are more resistant to mosquito biting to hold some promise.

14.2 Horse flies and deer flies (tabanids)

The most important groups are the genera *Tabanus* (horseflies, greenheads), *Chrysops* (deerflies, mangrove flies) and *Haematopota* (clegs or stouts). They are of minor importance as vectors of diseases, such as tularemia and certain arboviral diseases. In West and Central Africa, some species of the genus *Chrysops* transmit the filarial parasite *Loa loa*. Horse flies can transmit anthrax, anaplasmosis, some trypanosomes, tularemia and some helminthes infections. The tabanids are robust and strong fliers and they measure about 5–25 mm in length. They have a big head with apparent eyes that show iridescent colors. The mouthparts are big and pointed downward. The wings are clear entirely or have brownish color or spots. Wings are folded flat along the body when insect is at res. Females horse fly *Tabanus*

Figure 13.
Mansonia titillans.

Figure 14.
Tabanus trimaculatus.

trimaculatus Palisot de Beauvois (**Figure 14**) have scissor-like mouthparts that aim to cut the skin and then lap up the blood. Deer fly *Chrysops callidus* Osten Sacken (**Figure 15**), is blood sucking insects of humans and cattle. They are large flies with large brightly-colored compound eyes, and large clear wings with dark bands. They are in habit of hovering around the head and shoulders and biting people, and known for following moving animals and repeatedly buzzing the head [79].

This family (Tabanidae) comprises deer flies and horse flies. Still, the life cycle of several species is unfamiliar, however in those that are identified, there is often an aquatic phase in the cycle. Eggs are placed in moist areas including pools and streams. In about a week, larvae hatch out and stay in the bottom of pools habitually burrowing into mud where these nourish on various forms of biological material and often surviving as micro-predators. Several species hibernate in winter as larval stage, however in spring; larvae molt to a pupal stage (lasting for 2–3 weeks) and then adults emerge. The female tabanids are only blood suckers. Mouth parts in many species are fairly prominent and role like a spear otherwise stylet to puncture an area, and usually causing loss of blood afterward the fly has done nourishing. An adult female tabanid may take away nearly 0.2 cc of blood for each nourishing. Their bites are deep and painful, and the wounds often continue to bleed after the flies have left host [80].

14.3 Stable fly *Stomoxys calcitrans* (Linnaeus)

Stable flies (*Stomoxys*) occur around the world. Stable flies are dark, medium-sized flies, 5–6 mm in length, resembling house flies in shape and size, and are also

Figure 15.
Chrysops callidus.

Figure 16.
Stomoxys calcitrans.

known as biting house flies. They can be distinguished from house flies and other similar looking flies by their forwarded pointing mouthparts. They may be confused with tsetse flies (Glossina), and these can be distinguished from tsetse flies, which also have forward-pointing mouthparts, by their smaller size and the position of wings, which do not overlap at the back in stable flies when at rest. These create painful bites and are a severe annoyance to humans and animals. They are not significant as vectors of diseases. But, they occasionally play a part in spread of myiasis by carrying eggs of myiasis-producing fly *Dermatobia hominis* (Linnaeus) [81].

Fly *Stomoxys calcitrans* (**Figure 16**), is commonly called the stable fly, barn fly, biting house fly, dog fly or power mower fly. Unlike most members of the family Muscidae, *S. calcitrans* (sharp mouth plus kicking) and others of its genus suck blood from mammals. The eggs are put down in decomposing vegetation or manure and in the same location, larval and pupal stages progress by taking nearly 3 weeks to complete life cycle. Equally, females and males are blood feeders and severe pests of both animals and man. The larvae are creamy white in color and resemble those of the house fly. The pupae develop in dry areas in the soil. Development from egg to adult takes from 12 days to 2 months, depending on the temperature. They are not as important as vectors of disease; however, stable fly can transmit many organisms including anaplasmosis, anthrax and other blood-borne organisms [82].

14.4 Horn fly *Haematobia irritans* (Linnaeus)

Although a small fly, the adult of this species (Muscidae) is one of the most important ectoparasites of pastured cattle. Adults are half the size of a house fly (7 mm), gray in color with the large compound eyes and reduced antenna (**Figure 17**). In the life cycle, the eggs are laid on newly passed feces. Larvae are approximately 7 mm long, of pale yellow color and with a simple elongate body that lacks a sclerotized head. In that atmosphere, the complete life cycle takes place, generally taking about 2 weeks for completion. Typically, the adults exist in great numbers along the withers, base of the horns and caudal folds. The adults stay on animal for the whole time (excluding when eggs are being set down), however they feed only once or twice a day and males and females both are blood feeders. The adults fly typically takes position by face downward when sitting on an animal. Besides loss of blood along with heavy constant invasion, this fly looks to cause an excessive annoyance and irritation. Infection conduction comprises anaplasmosis and other blood-borne organisms.

Figure 17.
Haematobia irritans.

Managing of horn fly is commonly factual as soon as compost is either dried or often removed to break life sequence. Further operational control actions include anti-larvicidal mixtures, which are added either to diet or delivered as supplement. In latter cases, action must be on track before start of fly season [83].

14.5 Tsetse flies *Glossina* sp.

Tsetse flies occur only in tropical Africa and include all the species in the genus *Glossina*, which are placed in their own family Glossinidae. They are yellowish or dark brown, medium-sized flies and 6–15 mm in length. They can be distinguished from other large biting Diptera by their forward-pointing mouthparts. Tsetse flies bend their wings completely once they are relaxing so that one wing directly rests on top of other above their abdomens. Tsetse fly has also a long proboscis that spreads directly frontward and is attached to bottom of its head by a distinct bulb. Both sexual category are blood feeders and nourish on a wide-ranging of hosts also comprising man. Eggs hatch in the body of female and later on larval growth takes place, and then dropped larvae pupate instantly. The pupal stage nearly lasts for 3 weeks. This fly is a powerful vector for some diseases of man and animals comprising trypanosomiasis. They have a prominent economic impact in sub-Saharan Africa as the biological vectors of trypanosomes, which cause human sleeping sickness and animal trypanosomiasis, for instance, *Glossina brevipalpis* (Newstead) (**Figure 18**) is a vector of *Trypanosoma congolense* and *Trypanosoma vivax* [84].

14.6 Black flies

A black fly sometimes called a buffalo gnat, turkey gnat or white socks, is any member of the family Simuliidae. Black flies occur around the world and there are about 1300 species in the genus *Simulium* (**Figure 19**). The buffalo gnat blackflies are stout-bodied, about 1–5 mm long, and usually black in color, although orange and yellow species exist as well. They have relatively large eyes, legs are short, and the wings are short, broad and colorless. Black fly bites in daytime out of doors and some species prefer to feed only on certain parts of the body, for example, the legs or the upper part of the body. Black flies prefer to lay eggs in swift oxygen-rich running water in streams, rivers and spillways of dams, and are deposited on objects or near the surface of the water. In the tropics, the eggs usually hatch after 14 days. After the eggs hatch (1–4 weeks), larvae attach to the submerged objects and remain there for about a month. The larvae do not swim (usually symptomless), continuing attached to submerged flora, stones and other substrates, and forage on tiny suspended particles. Based upon climate, the larval stage persists from 1 week to many months. The pupae are as well attached to submerged things

Figure 18.
Glossina brevipalpis.

Figure 19.
Simulium *black fly.*

and when the larval stage pupates, adults develop in about a week. Although small in size, the adults are good flyers and may go several kilometers in search of food [85].

Onchocerciasis, too known as river blindness, is a sickness initiated by infection by the parasitic nematode *Onchocerca volvulus*. Warning signs comprise intense itching, bumps below the skin and loss of sight. The parasite worm is transported by the bites of a *Simulium* type black fly. Only adult females are blood feeders, wherein the best significant species are *Simulium neavei* Roubaud and members of *Simulium damnosum* Theobald complex. Additionally, black flies are of severe annoyance in numerous regions of the world for the reason that of their painful bites and from time to time huge numbers involved in invasions. Black fly bites can create localized inflammation and swelling, and extreme irritation of skin lasting for days or weeks. Usually, black flies do not come into houses, but bite in the daytime and outdoors, especially along riverbanks. Certain species show a strong preference for biting specific parts of the body, for example, *S. damnosum* in West Africa mainly attacks the legs. Most species feed predominantly on birds or mammals, while several feed on humans [86].

14.7 Phlebotomine sandflies

Sand flies (Psychodidae) are about 1.5–4 mm long, have a hairy exterior, visible black eyes and lengthy stilt-like legs. They have a typical jumping flight with several short flights and landings. Contrary to all other biting Diptera, when at rest, their wings are held upright above the body. Sand flies are minute blood sucking flies that are key as vectors of leishmaniasis and can cause a severe biting nuisance, but limited to a small area. Species that take place in the Mediterranean area can spread sand fly fever that is a viral disease likewise recognized as pappataci fever or 3-day fever. The breeding places for this genus appear to be mainly non-aquatic situations. The life cycle may last from 1 to 4 months, depending on species and temperature, although it usually lasts less than 45 days. Sand flies feed on plant juices, but mostly the females need a blood meal in order to develop eggs. The cattle provide an abundant source of blood, while the stables and houses provide suitable resting places. Blood is taken from humans and animals such as dogs, farm livestock, wild rodents, snakes, lizards and birds [87].

The sand fly *Phlebotomus papatasi* (Scopoli) (**Figure 20**), is the main vector of the Old World cutaneous leishmaniasis. It is distributed from Morocco to the Indian subcontinent and from southern Europe to central and eastern Africa [88].

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14.8 Biting midges

Biting midges (no-seeums, punkies) are blood sucking flies and about 1.5 mm in length. The most important genus *Culicoides*, is distributed worldwide and can cause a serious biting problem, as can the genus *Leptoconops.* These insects are vectors of the human filariae parasites *Mansonella ozzardi* and *Mansonella perstans* (Nematoda: Onchocercidae) that are mostly deliberated to be not hurtful to humans. These insects are termed as sand flies in certain regions of the world, however these may be differentiated from phlebotomine sand flies using the point that while midges are at relaxation wings are bent uniform on body; moreover, these frequently fly in crowds nearby head or other uncovered parts of body and do not flutter in a hopping mode by several landings and short flights, as is done by phlebotomine sand flies.

The lifecycle of this genus involves aquatic breeding places, elevated surface of mud or wet soil primarily temporary pools, decaying leaf litter and objects near or partially in water. The larvae feed on decaying organic matter and the time taken for development from egg to adult may be 2–4 weeks. It is an important vector for blue-tongue virus in many animal species as well as being a pest. Individual midges can cause a painful bite, but they are considered to be an especially severe pest because of their habit of attacking in swarms of hundreds or thousands. Ceratopogonidae is an example of family that includes serious blood-sucking *Culicoides sonorensis* Wirth & Jones (**Figure 21**) feeding both on humans and

Figure 20.
Phlebotomus papatasi.

Figure 21.
Culicoides sonorensis.

Figure 22.
Melophagus ovinus.

other mammals, and spread the livestock diseases blue tongue and African horse sickness [89].

14.9 Sheep Ked or sheep tick *Melophagus ovinus* Linnaeus

It is a fly from the family Hippoboscidae, brown and hairy in color and resembles a tick. This wingless fly is about 4–6 mm long and has a small head. They are blood-feeding parasites of sheep. The sheep ked feeds on the blood of host by inserting its sharp mouthparts into capillaries beneath the skin. The adult hippoboscids are well adapted to an existence on wool, hair and feathers for blood feeding. The life span of this fly is about 4 months with adult females retaining larvae internally until pupation and may produce 10–20 larvae by producing a single larva at a time. Pupae are attached directly to the wool, pupal stage lasts for 19–23 days and adult lives for 7–10 days. The entire life cycle of this fly takes place while it is on the infested animal. Other hippoboscid flies are important vectors for some avian diseases such as *Haemoproteus* sp. The sheep ked *Melophagus ovinus* (**Figure 22**), once remained a serious pest in the sheep industry. Several similar genera are present on wildlife including deer and elk. Adults ked can be killed using treatment dips and sprays most commonly containing ivermectin or pyrethrin. Use of injectable antihelminthics is also effective against some arthropods that have made this a less frequent problem [90].

15. Myiasis-producing Diptera

Myiasis is the invasion of tissue by fly larvae, which at least for a certain period, feed on the host's dead or living tissue, liquid body-substance or ingested food and such invasions can be benign in effect, but others may result in a variety of conditions, including death. When the invasion occurs in the intestinal tract, it is called intestinal myiasis, in stomach known as gastric myiasis, or there may be nasal myiasis and cutaneous myiasis, etc. Some species of flies that are not significant as adults are important as myiasis-producing larvae. Cutaneous myiasis is a skin invasion by larvae (maggots) of certain flies, and depending on the species of fly involved, there are three main types of skin infestation by fly larvae such as furuncular (pimple-like or boil-like) myiasis, wound myiasis and migratory myiasis [91].

Many of the flies that cause furuncular myiasis are commonly known as bot flies including *Dermatobia hominis*, *Cordylobia anthropophaga* (Blanchard & Berenger-Feraud), *Wohlfahrtia vigil* (Walker) and *Cuterebra* species. Many of the flies do not lay eggs on humans. Instead, the flies lay their eggs on other insects (such as mosquitoes) or on objects (such as drying laundry) that may come into contact with people's skin. Characteristic signs of furuncular myiasis comprise irritation, an impression of movement and on occasion a sharp piercing aching. In the beginning, people have a minor red bump, which can look like a common insect bite or creation of a furuncle (pimple). Later on, bump expands, and a slight opening may be evident in the center, opening may drain a clear yellowish fluid and on occasion a small portion of larva end is evident. Open wounds (traumatic), typically in homeless people, alcoholics and others in poor social circumstances, may become infested with fly larvae. The tissues that line the mouth, nose or eyes (mucosa) may also become infested [92]. The most common flies are screwworm flies such as *Cochliomyia hominivorax* and *Chrysomya bezziana* and *Wohlfahrtia magnifica* (Schiner) (**Figure 23**).

The most common sources of migratory (creeping) myiasis are flies that typically infest horses and cattle (Gasterophilus and Hypoderma flies). People can become infested if they have contact with infected animals. Less often, the flies lay eggs directly on people. Larvae do not stay in one spot and they burrow under the skin, causing itchy lesions. Diagnosis of fly larvae can be made on the size of larvae, location and host from which it is recovered, and characteristics of the spiracle openings located on the posterior of the larvae [93].

Warble flies of cattle are perhaps one of the most significant myiasis-producing problems of the cattle industry. There are two important species of the cattle grub, *Hypoderma lineatum* De Villiers Southern cattle grub and *Hypoderma bovis* (Linnaeus) Northern cattle grub. In broad-spectrum, life sequence of species contains adult flies that deposit eggs on body of host by sticking to furs, within some days eggs hatch and larvae enter into skin. Afterward, larvae transfer through host tissue and gather at esophagus wall. These from here, move to dermal tissue of host back, persist on cattle back for quite a few months and after that time these drop out to land for pupation. There are a number of indirect and direct reasons of hurt and fiscal loss which may be ascribed to invasions by these larvae. Mortalities may take place for the period of larval movement and at what time these are assembled in an area of esophagus. Indirect injuries are described as condensed milk making, weight loss otherwise low weight increases and less price of hide or carcass owing to presence of larvae. Common warble of rodents and rabbits *Cuterebra* sp., although common in wild rodents, infestations with this larvae are also occasionally seen on

Figure 23.
Wohlfahrtia magnifica.

dogs and cats. One species (*Cuterebra emasculator*) Fitch parasitizes the external reproductive organs of rodents and may have an effect on population numbers [94].

Sheep bots or head grub *Oestrus ovis* L., (**Figure 24**) of family Oestridae, is a bot which commonly enters the sinuses nasal and passages of sheep. Adults of fly place live larvae over nasal passages; from here these make their approach to frontal sinuses and attach themselves with mucus membranes. These persist for some months in this location and are sneezed out or ultimately fall out and pupate in soil. The pupae period lasts for around 3–6 weeks. When host is infested; generally there is a pus-filled ejection from the nostrils, resulting shaking of head vigorously, less appetite and grating of teeth by animal. Maximum of cases do not produce distinct clinical symbols even though expiry of animal may take place within a week after intensified signs. The indirect damages and serious situations causing from invasion are possibly the best reasons for starting treatment [95].

Horse stomach bot *Gasterophilus* sp., in the family Oestridae are several species of this parasite each of which has slightly different locations of attachment, primarily affecting horses and donkeys. The more common horse bot fly *Gasterophilus intestinalis* (DeGeer) (**Figure 25**) is an internal parasite of gastrointestinal tract, while other are *Gasterophilus nasalis* (Linnaeus) nose bot fly and *Gasterophilus haemorrhoidalis* (Linnaeus) throat bot fly. In mid-summer, adult flies are frequent and females lay eggs on hairs habitually on the belly, forelegs, inside the knees and flanks. When the horse licks these body parts, rubbing and moisture cause eggs to hatch. Larvae transfer to mucus membrane of lips and tongue ultimately creating their way to stomach or other places. At this point, these continue to attach till subsequent spring, as soon as these separate, pass out through feces, fall to ground and pupate. Some indirect and direct pathological modifications are linked to invasion. Modest invasions by bots can contribute with no apparent symbols, but strong invasions may be shown through intestinal syndromes. Probable interfering with ingestion and immersion of nutrients, irritation of mucus membranes, and obstacle of pyloric sphincter are very common [96].

Figure 24.
Sheep bot fly. Immature and mature larvae.

Figure 25.
Gasterophilus intestinalis *larva.*

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15.1 Cutaneous myiasis

Genus *Cochliomyia* in the family Calliphoridae includes blow fly *Cochliomyia hominivorax* (Coquerel) well-known as primary screwworm (**Figure 26**) for the reason that this larva creates myiasis and forages on live tissue producing pocket-like deep lesions in skin that might be enough harmful to host animals. But, *Cochliomyia macellaria* (Fabricius) is famous as secondary screwworm since its larva creates myiasis, however nourish on only necrotic tissue. Forensically, that species is significant since it is habitually linked o dead bodies and carcasses. All species in the family Calliphoridae have bristles on their merones, plumose arista and well-developed calypters. Both *C. macellaria* and *C. hominivorax* are metallic green to bluish green in major coloration and three black longitudinal stripes (vittae) on the notum of the thorax. The species *C. macellaria* has pale setulae on the fronto-orbital plate outside the row of frontal bristles, while *C. hominivorax* has dark setulae. The larvae of both *C. macellaria* and *C. hominivorax* have cylindrical bodies tapering anteriorly with 10 or more robust spines around the spiracular area and bands of small spines on each segment. The *C. hominivorax* larvae have distinctly pigmented tracheal trunks, while *C. macellaria* larvae do not have pigmented tracheal trunks, but bear spines in a V shape on the anal protuberance [97].

The gravid female screw worm fly is captivated on living animals to oviposition sites. These sites are any discharges, bites, wounds, etc., which may take place. For egg deposition, the naval of newborn animals is a common site. The eggs are of cream color, hatch in 24 hours and larvae enter the wound and begin feeding. The larvae burrow into tissue, enlarging the wound that cause severe pain to the host. Animals smaller than rabbits, usually do not survive due to infestations. Larger animals may surrender to repeated infestation or if larvae penetrate blood vessels. Death is usually caused by toxemia and or septicemia from bacterial invasion of the wound. After 5–7 days, the larvae drop, burrow into the first layer of topsoil and begin their pupation. This stage can last from 7 days at a warm temperature to as long as 2 months if the weather is much colder. After emerging from the pupa adult flies live around 2–3 weeks. Once the infestation commences, a dark brown or reddish-brown discharge begins leaking from the wound, sometimes accompanied by an unpleasant smell as the flesh begins to decay both in livestock and human victims [98].

These are various important species of parasites and necrotic tissue feeders since they are common and capable to parasitize abrasions and wounds on animals. Blow fly strike is multiparty, such as on sheep and some other animals. Altogether, these

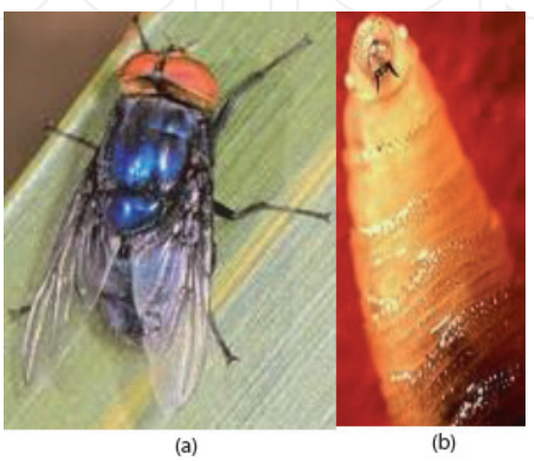

Figure 26.
Cochliomyia hominivorax. *(a) Adult, (b) Larva.*

are non-live tissue feeders and larvae mature in decomposing organic material. Identity of larvae is determined by morphologic features of the spiracle openings. In various cases, distinction from primary screwworm is of significance. Some species of blowflies are vital in occurrence of 'Limber-neck' or avian botulism. Epidemics are shared in both captive and free-ranging birds. Deceased birds aid as a food source of growing maggots that serve as resources of food and infection for other birds.

15.2 Treatments

Different treatments for controlling of invasions are available based on the dipterans circumstances and the parasite involved. Adults of Diptera are usually controlled by application of spray products such as pyrethrins and malathion, applied to premises and done directly at adult flies. Larvae of flies can be managed by different means liable to their location. Maximum myiasis creating larvae are controlled effectively with Ivermectin in the course of their migratory stage of life cycle. Many organophosphates (topical, sprays, etc.) are available as well. The programing of treatment can be imperative as killing of migrating larvae at specific time and location in the body can cause in tissue reactions and pathologic changes.

Long term control of midges and gnats requires trying to eliminate breeding sites such as wet areas or standing water. However, this type of control is not practical at large scale. Often, water should not be treated with any insecticide in an attempt to control gnats. The potential harm to the environment and wildlife is too great to justify an application for a temporary nuisance.

Because larvae require oxygen, blocking the skin opening of host may cause them to leave or at least come closer to the surface. When they are closer to the surface, it is easier to pull them out with forceps. Sometimes physicians inject an anesthetic into the skin, make a small incision and pull the larva out with forceps. The drug ivermectin, given by mouth or applied to the skin, also may kill the larva or cause it to leave host.

At certain times of the year, when livestock are most vulnerable to flies (castration, birthing, etc.,) if possible their daily inspections should be done. As with many things, prevention is the best cure and any open wound, even so small as a blister, is a potential infestation site, which should be treated accordingly with approved pesticides. In addition to the continued release of sterile males, a screwworm adult suppression system is now used, which involves a chemical attractant with dichlorvos.

16. *Dipteran* usage in industries

Insects harbor high potential for nonfood usage as antimicrobial effects, additives and even cosmetics and pharmaceuticals. Recently, farming insects have been emerged as a new source of protein and lipid production. Investigations have been performed for proteomics and lipidomics on black soldier fly *Hermetia illucens* (Linnaeus) of family *Stratiomyidae* (**Figure 27**) and blow fly (*L. sericata*) larvae. The result displayed great levels of lauric acid in soldier fly that after biological decomposition could even increase. Proteomics study exposed the presence of proteins like collagen with a cosmetic interest, and proteins with antimicrobial properties such as phenoloxidases and enzymatic actions, like trypsin and amylase. Black fly larvae can be used as fresh, frozen, freeze-dried or meals for feeding of animal proteins to fish and poultry. The substitution of 10% soybean meal by the same amount of fly larvae meal improves weight gain, conversion rate and carcass yield. Black fly can be a valuable candidate for mass rearing on agro-industrial wastes or by-products.

Figure 27.
Lucilia sericata*. (a) Adult, (b) Larvae.*

Furthermore, its rearing brings several collateral benefits, for example reducing the smell of decaying organic matter or the production of biofertilizer. Black fly larvae are capable to transform nutrients from plants, residues and other agricultural by-products into compounds that are digestible by monogastric animals. Such information exposes new opportunities for future research in cosmetic and pharmacological approaches to discover novel molecules of interests [99, 100].

17. Evolution and paleontology

Dipteran insects are endopterygotes that go through an essential metamorphosis. The ownership of a single pair of complete wings differentiates maximum of true flies from other insects having the word 'fly' in their names (whiteflies, scorpionflies, hangingflies, caddisflies and butterflies). They belong to the Mecopterida, alongside the Mecoptera. On the other hand, some true flies such as louse flies (Hippoboscidae) have been converted to secondarily wingless. The earliest fly fossils found so far are from the Triassic period [geologic period and system which spans 50.6 million years from the end of the Permian period 251.9 million years ago (Mya), to the beginning of the Jurassic period 201.3 (Mya)], about 240 million years ago. Phylogenetic analysis suggests that flies originated in the Permian period [geologic period and system, which spans 47 million years from the end of the Carboniferous period 298.9 million years ago (Mya), to the beginning of the Triassic period 251.902 (Mya)], about 260 million years ago. Diptera belongs to panorpoid complex that consists of Trichoptera (caddisflies), Mecoptera (scorpionflies), Siphonaptera (fleas), Lepidoptera (butterflies and moths) and Diptera (true flies). The whole are thought to have grown as of an ancestor, which existed in moss, and four-winged insects that look like crane flies and have been well-maintained as fossils in Permian deposits, rocks set down between 299 million and 251 million years before. Strata of the Lower Jurassic System (from about 201 million to 174 million years back) comprise several true midges. Initial Brachycera initiated to be visible in the Mesozoic Era (about 252 million–66 million years past). Cyclorrhapha seemed in the Cretaceous period (145 million–66 million years back). By the finish of the Eocene Epoch, certain 34 million years before, maximum new families of flies have been developed. Flies in copal and amber dated to the Oligocene Epoch (about 34 million–23 million years past) are related to living genera.

A determined phylogeny for flies delivers a background for developmental, genomic and evolutionary homework by facilitating assessments across model organisms. Up till now, recent research has advocated that fly relations have been out of sight by manifold episodes of fast diversification. A phylogenomic estimate of fly relations based on morphology and molecules has been delivered from 149 of 157 families, comprising 30 kb from complete mitochondrial genomes and 14 nuclear

loci pooled with 371 morphological characters. Manifold studies display support for traditional groups (Brachycera, Cyclorrhapha and Schizophora) and verify contentious discoveries, for instance, the anomalous Deuterophlebiidae as the sister cluster to entire remaining Diptera. Conclusions disclose that the closest lineages of the Drosophilidae are much adjusted parasites (including the wingless Braulidae) of bees and other insects. Moreover, micro-RNAs have been used to decide a node with suggestions for evolution of embryonic development in Diptera. It has been confirmed that flies practiced three episodes of quick radiation of lower Diptera (220 Mya), lower Brachycera (180 Mya) and Schizophora (65 Mya), and a number of life history changeovers to phytophagy, hematophagy and parasitism in the history of fly evolution above 260 million years [101].

18. Conclusion

Flies are one of four super radiations of insects (along with beetles, wasps and moths) that account for the majority of animals life on earth. This is one of the largest insect orders in the world and includes many familiar insects such as mosquitoes, midges, sand flies, house flies and blow flies. This handsome book chapter definitive works on creatures of the order Diptera, by combining scholarly thoroughness and new perspective on descriptions, diversity, life histories, behavior, classifying and identifying, interactions with plants and animals, origins and distribution, transmitting diseases, pollinating plants, disposing of dung and carrion, natural life, and gives advice on how to control them as well as a detailed global overview of fly families and subfamilies on the planet. Diptera can be distinguished by the features like one pair of membranous wings, hind wings are reduced to small club like structures called halteres used as stabilizers during flight, sucking mouthparts, large compound eyes and short simple antennae, frilled or bushy in mosquitoes and crane flies. Flies mate while flying, eggs are usually laid on an appropriate food source, larvae complete development where these are laid and pupate in the substrate, which may be soil, plant tissue or animal tissue, organic matter and water. Owing to sucking and piercing mouthparts, adult flies are able to only ingest liquid foods, mostly digestion is to some extent external and salivary secretions are presented to liquefy diet and then softened product is consumed up. Some march flies and mosquitoes with their proboscis, pierce skin of prey and then suck up blood. Larvae of these insects order generally feed on decomposing moist food things such as fungi, carrion, rotting vegetable matter and dung, while some are parasites or predators of other animals. Partakers of this order have the greatest diversity of species and are found in almost all types of terrestrial and freshwater habitats. Diptera includes species known for their ubiquity (*M. domestica* house fly), their role as pests (*Anopheles gambiae* Giles malaria mosquito) and their value as model organisms across the biological sciences (*Drosophila melanogaster* Meigen). Many species of Diptera are important due to the role they play in disease transmission; such as biting midge (no-see-ums, sand flies) attacks in areas of low light without wind; gnats attack at hairline and are active during moist times (early spring); black fly bites during day near streams, is attracted to dark moving objects) and disease vector for onchocerciasis; horse fly, deer fly or gad fly bite on warm, cloudy days; sand fly (small, moth-like insect) bites at night in damp areas and is disease vector for leishmaniasis; snipe fly bites during daytime and is risk of severe allergic reaction; stable fly bites during daytime (especially during thunder storms); and tsetse fly bites during daytime even through clothing and is disease vector for African trypanosomiasis. In practice, protection of communities and animals is sometimes possible by avoiding places where mosquitos and biting flies are known

to rest or breed, and by not visiting risky places during peak biting hours could be an effective way to reduce their exposure to biting insects and the transmission of diseases.

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