FLIES

OF

PUBLIC HEALTH IMPORTANCE

AND

THEIR CONTROL

Training Guide - Insect Control Series

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
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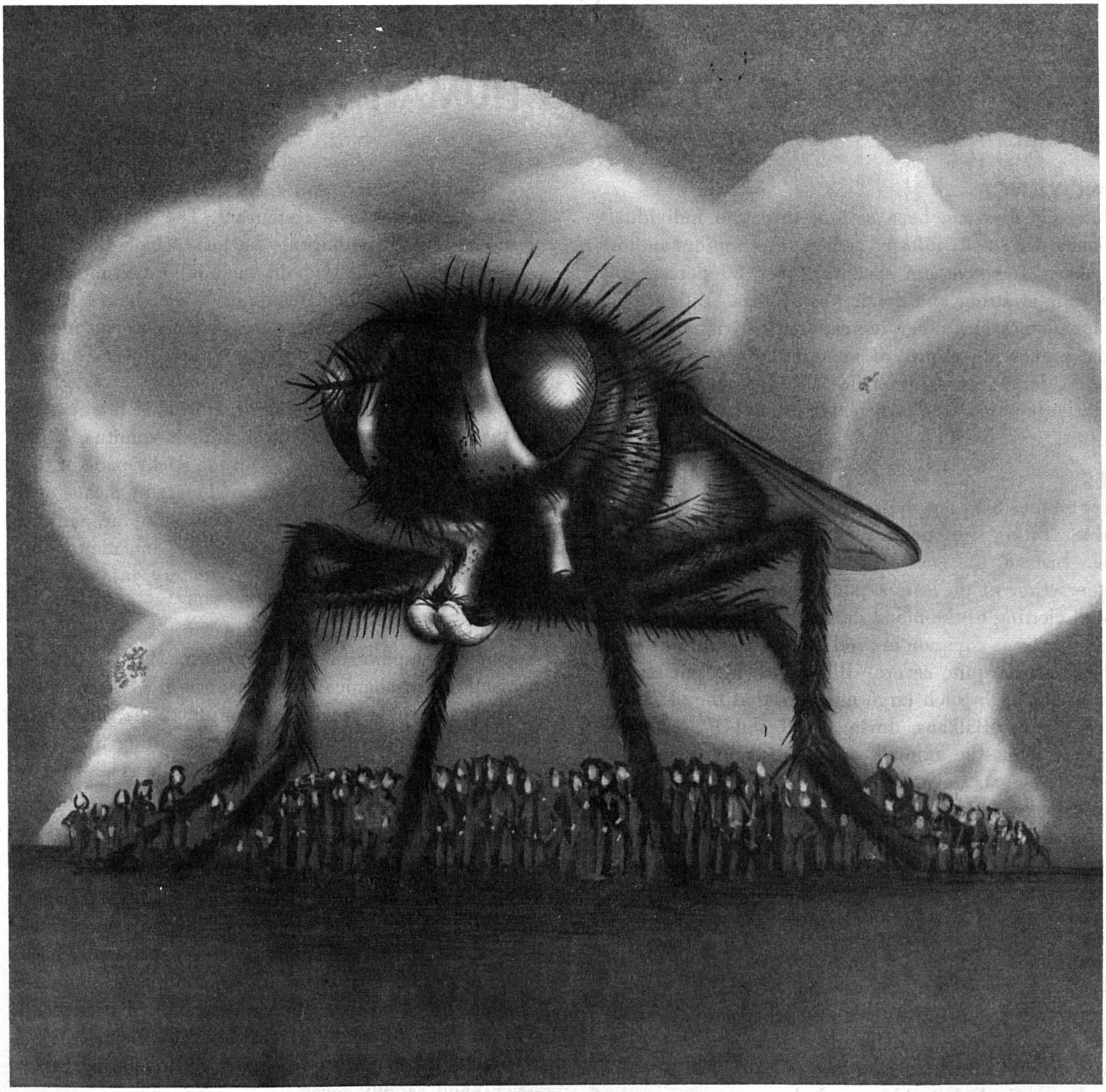


INTRODUCTION

Flies have been the intimate companions of man since long before the dawn of recorded history. Year after year, they have annoyed him, and have plagued him with vicious bites. Fly larvae have infested the flesh of man and of his domestic animals, and have attacked, and destroyed man's crops. More important, flies have carried disease (typhoid, dysentery, diarrhea, African sleeping sickness, onchocerciasis, and many others) and death to millions of people the world over. Today it is recognized that flies constitute one of the greatest of public health hazards, and that the abatement of fly populations is essential to the control of many serious and widespread diseases.

Effective control of flies is dependent upon accurate recognition of species, knowledge of the life cycle and habits of problem species, and an understanding of the dynamics of fly populations. Present methods of fly control are only partially effective; ready answers cannot be given to every fly control problem. However, recognized techniques, judiciously employed, can bring about a dramatic reduction in numbers of flies, and can thereby end transmission of fly-borne disease.

FLIES IN RELATION TO HUMAN WELFARE

ANNOYANCE

Domestic flies can be a serious threat to individual efficiency. In a fly-infested office, the senior author has observed employees spending over 50 percent of their time swatting and driving away flies. Biting flies disrupt picnics and other recreational activities as well as the pioneering efforts of mankind. In Canada, for example, large areas of fertile land remain unsettled, due in large part to the presence of annoying and biting flies.

BITES

Not all flies bite, but those which do can cause serious trouble. Biting flies do not have venom in the usual sense. Instead, the effects of their bites are the result of a reaction to the saliva poured into the wound to prevent clotting of the blood during the feeding process. The stable fly is common around human habitations and its bite can be quite severe. Black flies bite viciously, often attacking in such large numbers that they kill the victim. In the Balkans, during 1923 and 1924, thirty thousand domestic animals were killed by black fly attack. Eye-gnats do not bite, but their rasping mouth parts damage the delicate membranes of the eye. Deer flies, horse flies, sand flies, punkies, and other biting flies attack man and cause him great discomfort. In susceptible individuals, the bites may produce severe lesions, high fever and even general disability (West, 1958).

MYIASIS

Many species of flies are capable of laying eggs or larvae on the flesh of mammals and other animals. The larvae thus deposited can invade the flesh of the host animal producing a condition known as *myiasis.* Wild animals, particularly rabbits and deer, are commonly afflicted, as are many domestic animals, especially cattle and sheep. Human myiasis, while not common, occurs in all parts of the United States as well as in most other countries (James, 1947; Scott, 1962).

MECHANICAL TRANSMISSION OF DISEASE

Many flies, particularly the house fly and other domestic flies, have filthy habits which make them efficient mechanical vectors of disease (Busvine, 1959). *As a typical example:*

A house fly feeds on human feces in a privy used by a typhoid carrier, and then feeds on meat salad being prepared in a restaurant. The fly inoculates the food with pathogenic bacteria (including *Salmonella typhi,* the typhoid bacillus) which multiply rapidly in this ideal medium. When, hours later, the meat salad is eaten, the restaurant customers become infected, and develop typhoid fever (figure 5.1).

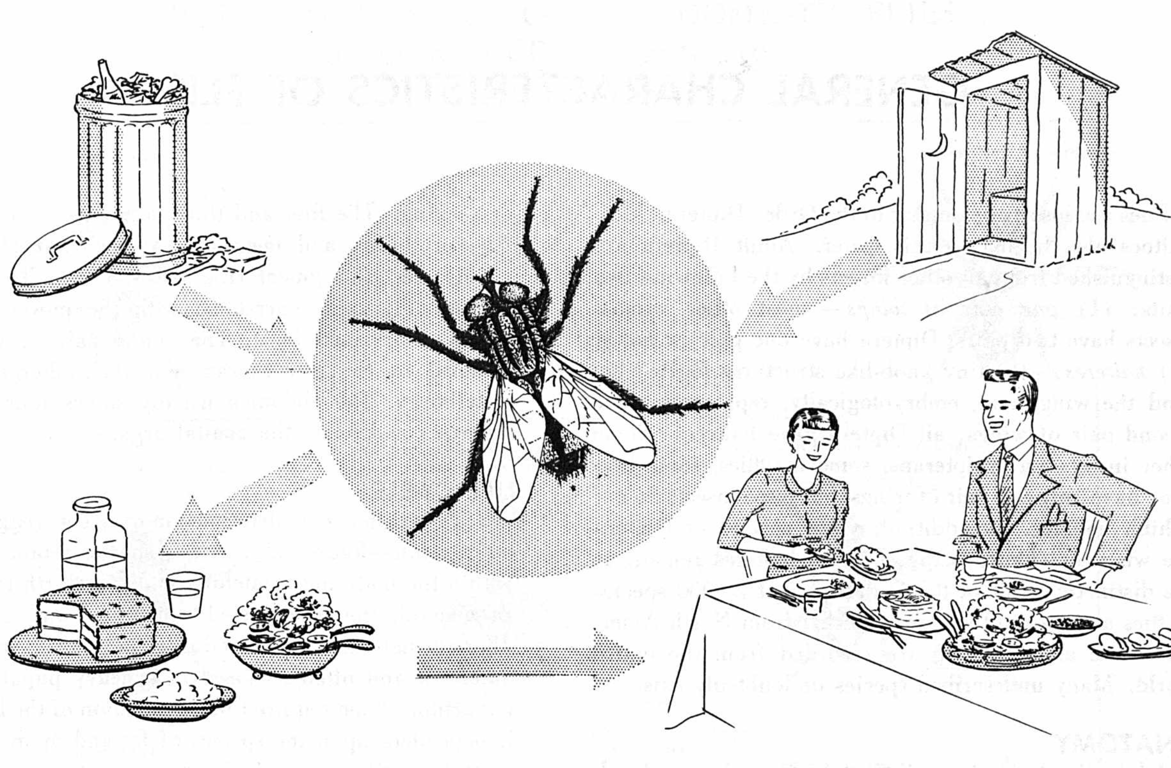
Flies carry disease-causing organisms in 5 ways: (1) on their mouth parts, (2) through their vomitus, (3) on their body and leg hairs, (4) on the sticky pads of their feet, and (5) through the intestinal tract by means of fly feces (Radvan, 1960). Diseases transmitted mechanically by domestic flies (such as the house fly) include typhoid, paratyphoid, cholera, bacillary dysentery, infantile diarrhea (Verhoestraete and Puffer, 1958) amoebic dysentery, giardiasis, pinworm, roundworm, whipworm, hookworm, and tapeworms (Hale, *et al.,* 1960). Diseases transmitted mechanically by rasping flies (such as the eye-gnat) include trachoma, conjunctivitis, and yaws. Diseases transmitted mechanically by biting flies (such as the deer and horse flies) include anthrax and tularemia (Lindsay and Scudder, 1956; DeCoursey and Otto, 1956; Knuckles, 1959).

BIOLOGICAL TRANSMISSION OF DISEASE

Many flies, particularly biting flies, are involved in the biological transmission of some of the most serious and commonest of vector-borne diseases such as African sleeping sickness (Ashcroft, 1959) and the leishmaniases (Deane, 1959). Other diseases transmitted biologically by flies include onchocerciasis (blinding filariasis) loiasis (African eye-worm disease) bartonellosis (oroya fever) and sandfly fever.

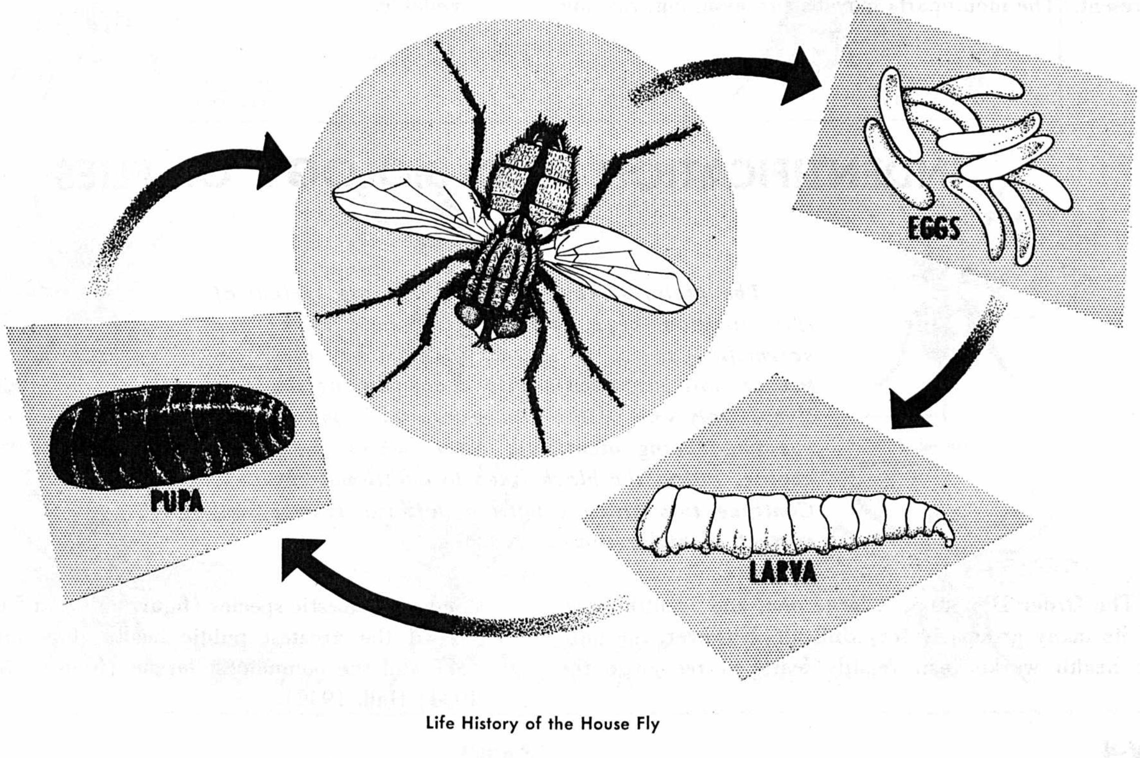
AGRICULTURAL IMPORTANCE

Many species of flies attack and damage plants directly (Hessian fly, cabbage maggot, onion maggot, apple maggot, clover seed midge, seed corn maggot, and others). Some flies transmit plant diseases (blackleg of cabbage; bacterial soft rot of vegetables; fire blight of apple, pear, and quince; ergot of rye and wheat; olive knot; bacterial rot of apple; leaf curl of cotton; etc.). In addition, flies annoy, cause myiasis in, and transmit diseases to domestic animals.



Mechanical Transmission of Disease by Flies

Figure 5.1



Life History of the House Fly

Figure 5.2

GENERAL CHARACTERISTICS OF FLIES

Flies are insects belonging to the Order Diptera. Mosquitoes also belong to this order. Adult Diptera are distinguished from all other insects by the following two traits: (1) *one pair of wings* — most other winged insects have two pairs, Diptera have one pair or none; (2) *halteres* — the tiny knob-like structures located behind the wings and, embryologically, representing the second pair of wings; all Diptera have halteres. Some other insects (strepsipterans, some mayflies, some beetles) have only one pair of wings, but these insects do not exhibit halteres. In addition, a few species of Diptera are wingless (figure 5.15), but the halteres remain as the distinctive trait of the Order. About 20,000 species of flies and mosquitoes are recorded from North America, while about 90,000 are recorded from the entire world. Many undescribed species undoubtedly exist.

ANATOMY

Adult flies have three distinct body regions — head, thorax, and abdomen. Most have very large compound eyes which occupy a great portion of the external surface of the head. One pair of antennae ("feelers") is present. The mouthparts may be for sponging, rasping, or sucking. The first and third segments of the thorax (the prothorax and metathorax) are dwarfed by the massive second segment (the mesothorax). The size of the mesothorax is correlated with the powerful wing muscles contained in it. The single pair of wings is fastened to the mesothorax and the halteres to the metathorax. The abdomen usually shows four to nine segments and bears the genital organs.

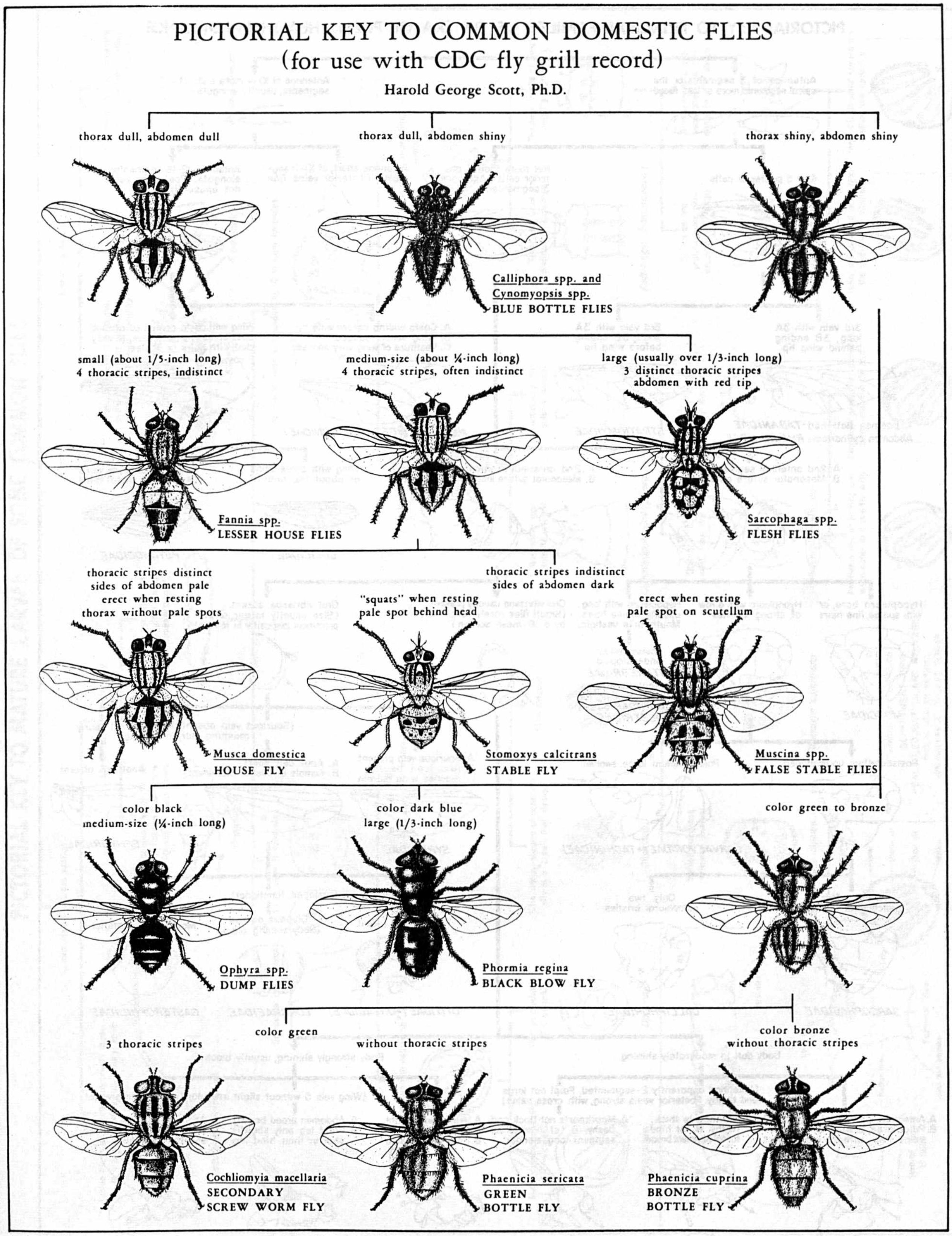
LIFE CYCLE

Flies exhibit complete metamorphosis (egg, larva, pupa, adult—figure 5.2). A few species retain the eggs within the body until hatching and give birth to larvae. In general, the larvae feed differently and occupy a different habitat from the adult. The pupae are usually quiescent and often enclosed in a heavy pupal skin or puparium. Time required for completion of the life cycle is dependent upon the species of fly and upon environmental conditions, particularly temperature. Choice of larval habitat, made by the adult female, differs with each species, and may also differ seasonally, geographically, and with regard to types of habitats that are available.

INDENTIFICATION AND BIOLOGY OF FLIES

The pictorial keys in this guide are typical of identification keys found in reference works and scientific papers. At the top of each key there are two or more statements with accompanying illustrations. Only one of the statements will apply to the specimen being identified. After making the proper choice, follow the black lines to additional choices. Continue this process until a definite answer (and correct identification) is reached.

The Order Diptera is a large one, and identification of its many groups is very difficult. However, the public health worker can readily learn to recognize the common domestic species (figures 5.3 and 5.6) the families of the greatest public health importance (figure 5.4) and the commonest larvae (figure 5.5) (Curran, 1934; Hall, 1948).



PICTORIAL KEY TO COMMON DOMESTIC FLIES
(for use with CDC fly grill record)
Harold George Scott, Ph.D.
thorax dull, abdomen dull
thorax dull, abdomen shiny
thorax shiny, abdomen shiny
Calliphora spp. and
Cynomyopsis spp.
BLUE BOTTLE FLIES
small (about 1/5-inch long)
4 thoracic stripes, indistinct
medium-size (about ¼-inch long)
4 thoracic stripes, often indistinct
large (usually over 1/3-inch long)
3 distinct thoracic stripes
abdomen with red tip
Fannia spp.
LESSER HOUSE FLIES
Sarcophaga spp.
FLESH FLIES
thoracic stripes distinct
sides of abdomen pale
erect when resting
thorax without pale spots
thoracic stripes indistinct
sides of abdomen dark
"squats" when resting
pale spot behind head
erect when resting
pale spot on scutellum
Musca domestica
HOUSE FLY
Stomoxys calcitrans
STABLE FLY
Muscina spp.
FALSE STABLE FLIES
color black
medium-size (¼-inch long)
color dark blue
large (1/3-inch long)
color green to bronze
Ophyra spp.
DUMP FLIES
Phormia regina
BLACK BLOW FLY
color green
3 thoracic stripes
without thoracic stripes
color bronze
without thoracic stripes
Cochliomyia macellaria
SECONDARY
SCREW WORM FLY
Phaenicia sericata
GREEN
BOTTLE FLY
Phaenicia cuprina
BRONZE
BOTTLE FLY

Figure 5.3

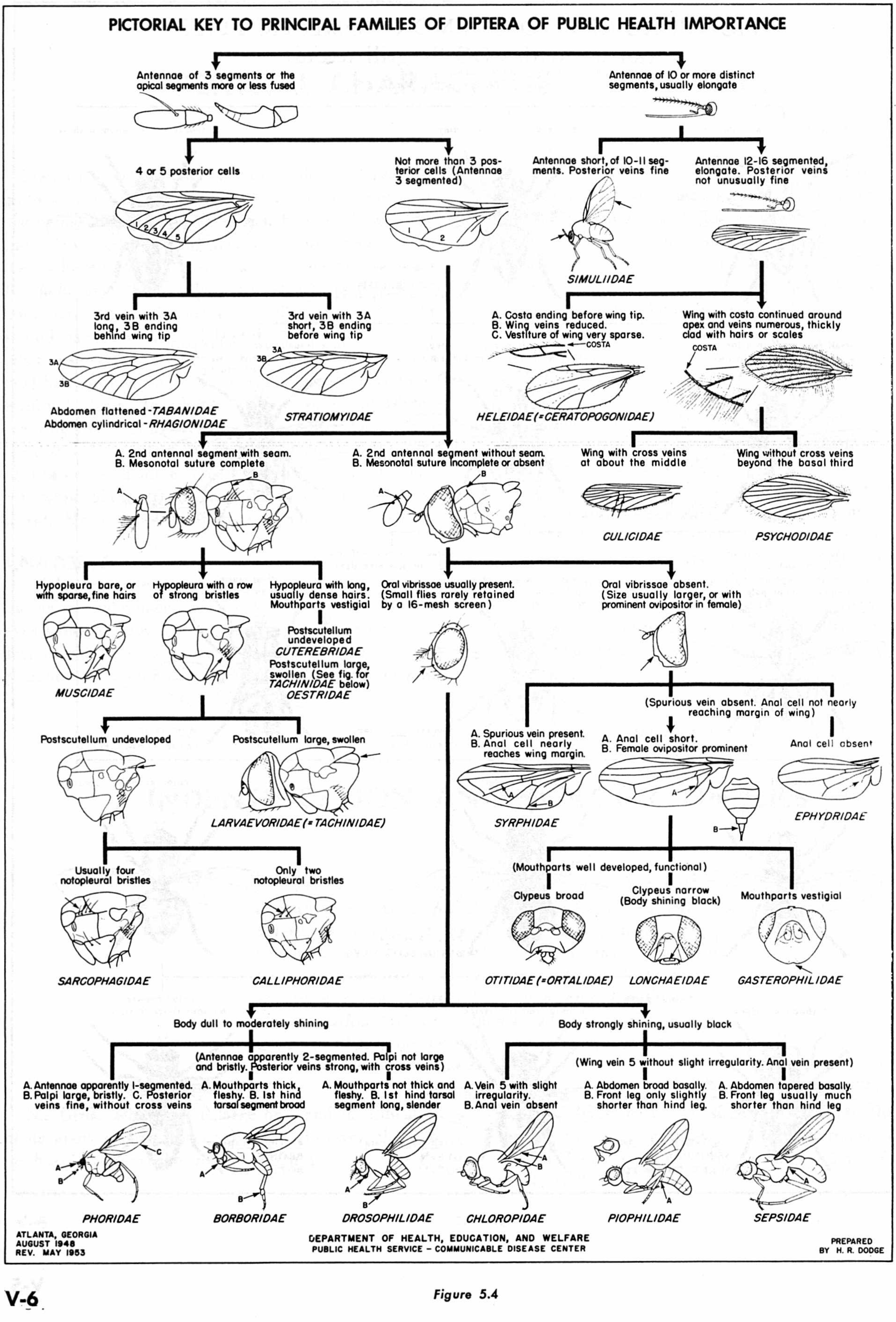
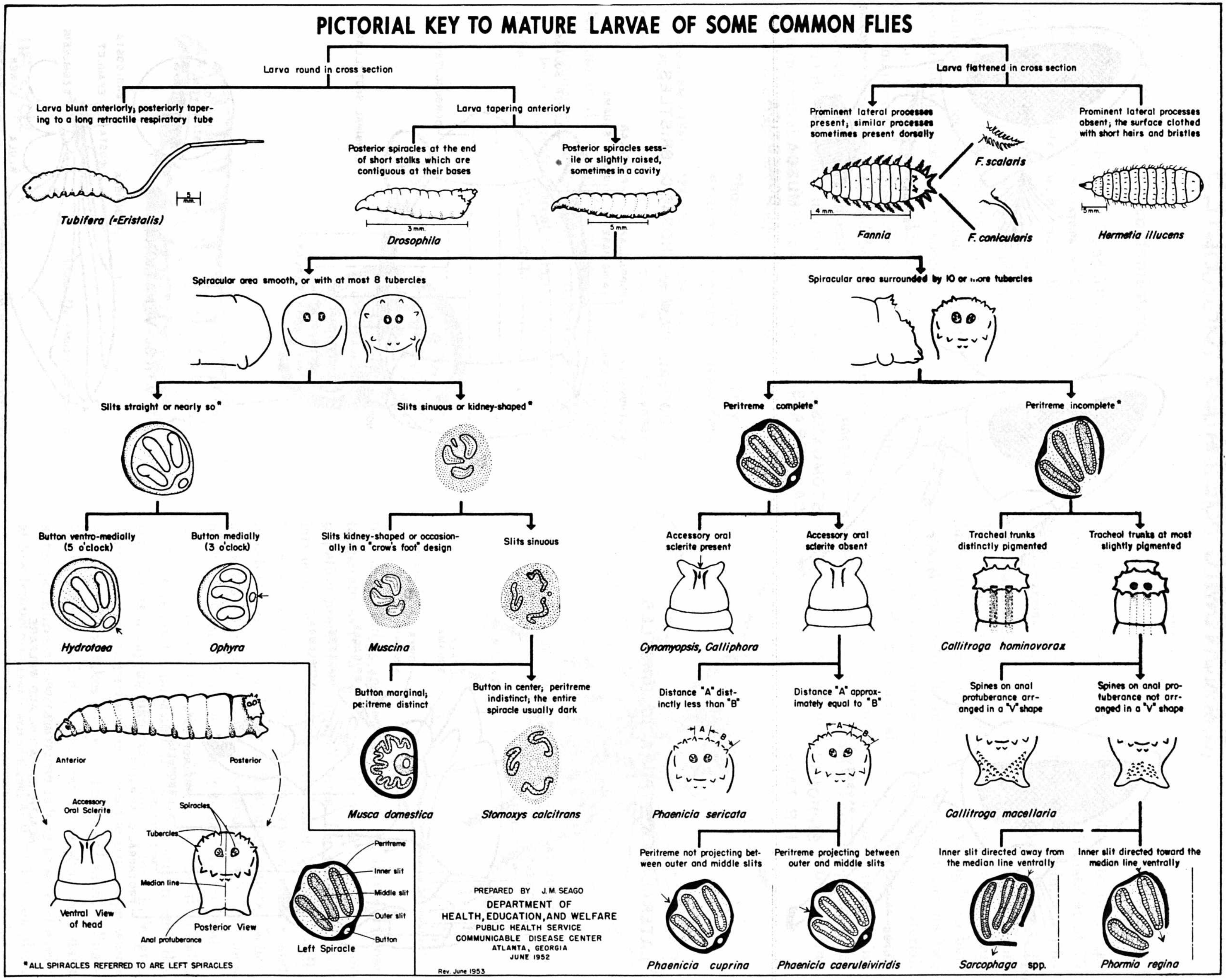
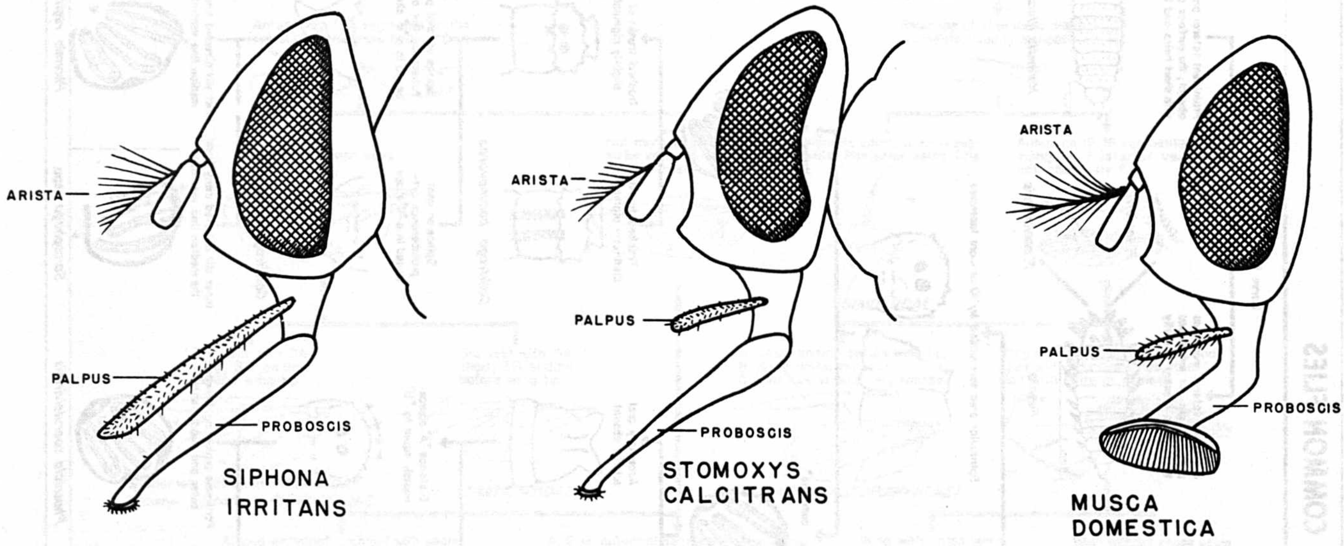

PICTORIAL KEY TO PRINCIPAL FAMILIES OF DIPTERA OF PUBLIC HEALTH IMPORTANCE
Antennae of 3 segments or the apical segments more or less fused
Antennae of 10 or more distinct segments, usually elongate
4 or 5 posterior cells
1 2 3 4 5
Not more than 3 posterior cells (Antennae 3 segmented)
1 2
Antennae short, of 10-11 segments. Posterior veins fine
SIMULIIDAE
Antennae 12-16 segmented, elongate. Posterior veins not unusually fine
3rd vein with 3A long, 3B ending behind wing tip
3A
3B
Abdomen flattened - TABANIDAE
Abdomen cylindrical - RHAGIONIDAE
3rd vein with 3A short, 3B ending before wing tip
3A
3B
STRATIOMYIDAE
A. Costa ending before wing tip.
B. Wing veins reduced.
C. Vestiture of wing very sparse.
COSTA
HELEIDAE (=CERATOPOGONIDAE)
Wing with costa continued around apex and veins numerous, thickly clad with hairs or scales
COSTA
A. 2nd antennal segment with seam.
B. Mesonotal suture complete
A
B
A. 2nd antennal segment without seam.
B. Mesonotal suture incomplete or absent
A
B
Wing with cross veins at about the middle
CULICIDAE
Wing without cross veins beyond the basal third
PSYCHODIDAE
Hypopleura bare, or with sparse, fine hairs
MUSCIDAE
Hypopleura with a row of strong bristles
Hypopleura with long, usually dense hairs. Mouthparts vestigial
Postscutellum undeveloped
CUTEREBRIDAE
Postscutellum large, swollen (See fig. for TACHINIDAE below)
OESTRIDAE
Oral vibrissae usually present. (Small flies rarely retained by a 16-mesh screen)
Oral vibrissae absent. (Size usually larger, or with prominent ovipositor in female)
Postscutellum undeveloped
Postscutellum large, swollen
LARVAEVORIDAE (= TACHINIDAE)
(Spurious vein absent. Anal cell not nearly reaching margin of wing)
A. Spurious vein present.
B. Anal cell nearly reaches wing margin.
A
B
SYRPHIDAE
A. Anal cell short.
B. Female ovipositor prominent
A
B
Anal cell absent
EPHYDRIDAE
Usually four notopleural bristles
SARCOPHAGIDAE
Only two notopleural bristles
CALLIPHORIDAE
(Mouthparts well developed, functional)
Clypeus broad
OTITIDAE (=ORTALIDAE)
Clypeus narrow (Body shining black)
LONCHAEIDAE
Mouthparts vestigial
GASTEROPHILIDAE
Body dull to moderately shining
Body strongly shining, usually black
(Antennae apparently 2-segmented. Palpi not large and bristly. Posterior veins strong, with cross veins)
A. Antennae apparently 1-segmented. B. Palpi large, bristly. C. Posterior veins fine, without cross veins
A
B
C
PHORIDAE
A. Mouthparts thick, fleshy. B. 1st hind tarsal segment broad
A
B
BORBORIDAE
A. Mouthparts not thick and fleshy. B. 1st hind tarsal segment long, slender
A
B
DROSOPHILIDAE
(Wing vein 5 without slight irregularity. Anal vein present)
A. Vein 5 with slight irregularity. B. Anal vein absent
A
B
CHLOROPIDAE
A. Abdomen broad basally. B. Front leg only slightly shorter than hind leg.
A
PIOPHILIDAE
A. Abdomen tapered basally. B. Front leg usually much shorter than hind leg
A
SEPSIDAE
ATLANTA, GEORGIA
AUGUST 1948
REV. MAY 1953
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE - COMMUNICABLE DISEASE CENTER
PREPARED BY H. R. DODGE

Figure 5.4

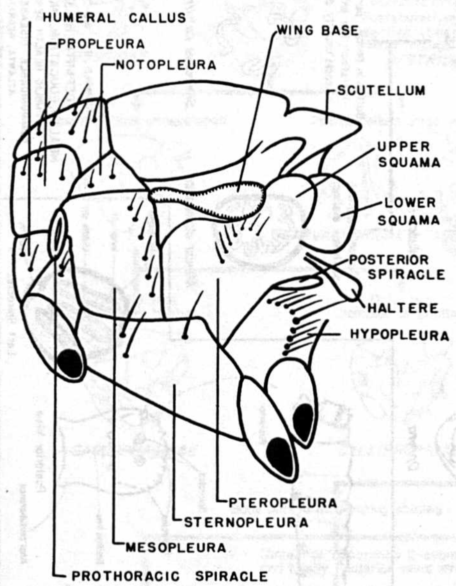
Figure 5.5


PICTORIAL KEY TO MATURE LARVAE OF SOME COMMON FLIES
Larva round in cross section
Larva flattened in cross section
Larva blunt anteriorly; posteriorly tapering to a long retractile respiratory tube
5 mm.
Tubifera (=Eristalis)
Larva tapering anteriorly
Posterior spiracles at the end of short stalks which are contiguous at their bases
3 mm.
Drosophila
Posterior spiracles sessile or slightly raised, sometimes in a cavity
5 mm.
Prominent lateral processes present; similar processes sometimes present dorsally
4 mm.
Fannia
F. scalaris
F. canicularis
Prominent lateral processes absent; the surface clothed with short hairs and bristles
5 mm.
Hermetia illucens
Spiracular area smooth, or with at most 8 tubercles
Spiracular area surrounded by 10 or more tubercles
Slits straight or nearly so*
Slits sinuous or kidney-shaped*
Peritreme complete*
Peritreme incomplete*
Button ventro-medially (5 o'clock)
Hydrotaea
Button medially (3 o'clock)
Ophyra
Slits kidney-shaped or occasionally in a "crow's foot" design
Muscina
Slits sinuous
Button marginal; peritreme distinct
Musca domestica
Button in center; peritreme indistinct; the entire spiracle usually dark
Stomoxys calcitrans
Accessory oral sclerite present
Cynomyopsis, Calliphora
Accessory oral sclerite absent
Distance "A" distinctly less than "B"
A
B
Phaenicia sericata
Distance "A" approximately equal to "B"
A
B
Peritreme not projecting between outer and middle slits
Phaenicia cuprina
Peritreme projecting between outer and middle slits
Phaenicia caeruleiviridis
Tracheal trunks distinctly pigmented
Callitroga hominovorax
Tracheal trunks at most slightly pigmented
Spines on anal protuberance arranged in a "V" shape
Callitroga macellaria
Spines on anal protuberance not arranged in a "V" shape
Inner slit directed away from the median line ventrally
Sarcophaga spp.
Inner slit directed toward the median line ventrally
Phormia regina
Anterior
Posterior
Accessory Oral Sclerite
Ventral View of head
Spiracles
Tubercles
Median line
Anal protuberance
Posterior View
Peritreme
Inner slit
Middle slit
Outer slit
Button
Left Spiracle
*ALL SPIRACLES REFERRED TO ARE LEFT SPIRACLES
PREPARED BY J. M. SEAGO
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
COMMUNICABLE DISEASE CENTER
ATLANTA, GEORGIA
JUNE 1952
Rev. June 1953

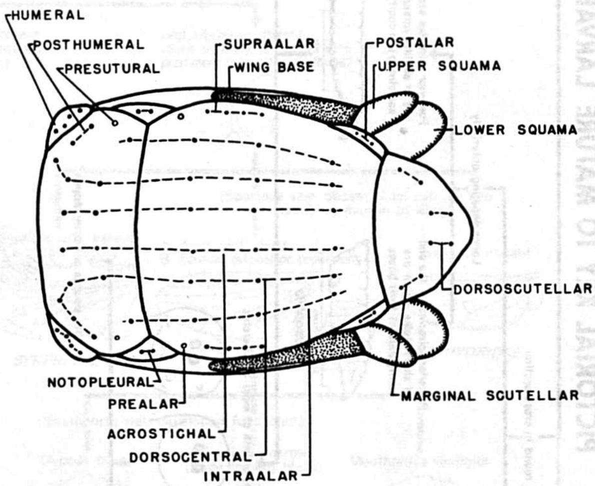
TAXONOMIC DETAILS OF FLIES



LATERAL VIEW— THORACIC BRISTLES



DORSAL VIEW — THORACIC BRISTLES



WING VENATION

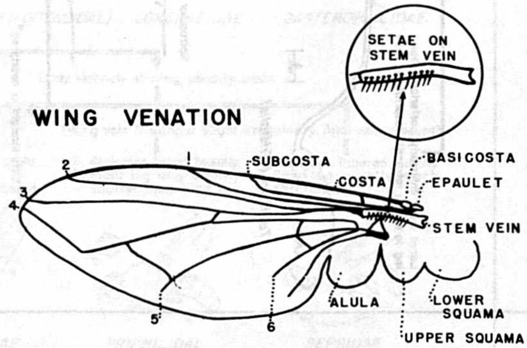


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Figure 5.6

HOUSE FLY AND RELATED FORMS (Muscidae)

THE HOUSE FLY *(Musca domestica)*

The house fly (figures 5.7 and 5.8) is one of the most widely distributed insects, as well as the one most frequently associated with man. It has followed man around the earth, and except for the Arctic, Antarctic, and areas of extremely high altitude, has successfully adapted itself to conditions in and around human habitations. It occurs throughout the United States, and is usually the predominant species found in homes and restaurants. Generally speaking, house flies make up the vast majority of domestic fly populations in the southwestern United States, and become relatively less predominant northward and eastward across the country. Typical fly trap counts taken in mid-fly season in southwestern central, and northeastern cities illustrate this (Schoof, Savage, and Dodge, 1955-1956):

	Phoenix Arizona	Topeka Kansas	Troy New York
Bottle and Blow Flies	122 (4%)	3339 (44%)	3107 (82%)
House Flies	2978 (96%)	3920 (52%)	325 (9%)
Others	6 (<1%)	316 (4%)	364 (10%)

Because of the house fly's close association with man, its abundance and its ability to transmit disease, it is considered a greater threat to human welfare than any of the other species (West, 1951).

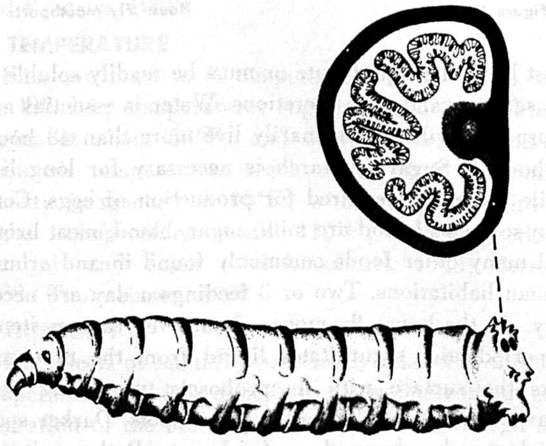


Figure 5.7 House Fly *(Musca domestica)*

LIFE CYCLE

The developmental stages of the house fly require from 8 to 20 days under average summer conditions (figure 5.2). The female begins egg laying within 4 to 20 days after emergence as an adult. The small, white, oval eggs (about 1/25-inch long) are deposited in batches of 75 to 150, with 5 or 6 batches being laid during the lifetime of the average female. Eggs are usually placed in cracks and crevices in the breeding medium away from direct light. Hatching occurs 12 to 24 hours after laying, during the summer months. The active young larva burrows at once into the breeding material using its two mouth hooks for tearing and loosening food material, and for working its way along. The three larval stages last from 3 to 24 or more days. The usual time during warm weather is 4 to 7 days. Larvae regulate their temperature by moving to various levels in the breeding medium. Studies indicate that feeding larvae choose temperatures from 86°F. to 95°F., while those ready for pupation prefer lower temperatures. The distribution of larvae in the breeding materials under natural conditions is believed to depend chiefly on temperature and moisture, and to a lesser extent upon odors. When growth is completed, the larvae migrate to drier portions of the medium or leave it entirely to burrow into soil, or under debris, for pupation (Minkin and Scott, 1960).

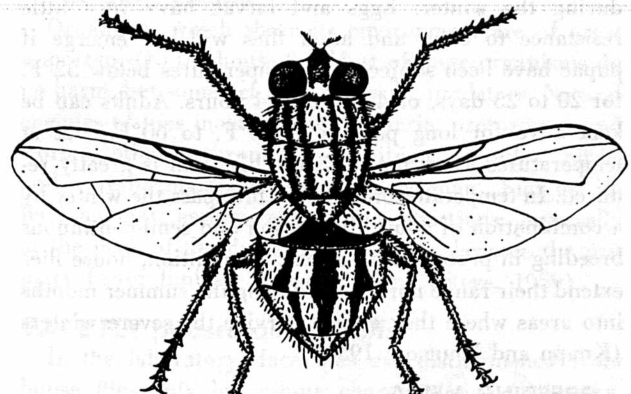


Figure 5.8 House Fly *(Musca domestica)*

When ready for pupation, the larva contracts until the skin forms a capsule-like case about ¼-inch in length. This case (the puparium) encloses the true pupa which is immobile and takes no food. The pupal stage ordinarily occupies 4 to 5 days, but may be as short as 3 days at temperatures around 95°F., or as long as several weeks at low temperatures. When the pupal period is complete, the fly breaks open the end of the puparium by the expansion of a bladderlike organ, the ptilinum, located on the front of the head. The fly then works its way out of the puparium and up to the surface of the soil. Here it crawls about rapidly while its wings unfold and the body expands, dries, and hardens. This requires about one hour under summer conditions. Complete activity is reached in about 15 hours. Mating may take place any time after complete activity is assumed.

Two or more house fly generations per month may be produced during warm weather. Because of the rapid rate of development and the large number of eggs produced per female, populations build up rapidly, increasing gradually during the spring and summer and reaching the maximum in late summer or early fall. However, in some south central and southwestern areas, densities may be great during the spring, show a marked decline during the hot, dry midsummer, and be the greatest during the late fall. Population densities vary considerably from year to year, even in the same area. Breeding continues throughout the year in tropical and subtropical regions while in more northern areas it is interrupted during the winter. Eggs and larvae have very little resistance to cold, and adult flies will not emerge if pupae have been subjected to temperatures below 52°F. for 20 to 25 days, or 48°F. for 24 hours. Adults can be kept alive for long periods at 50°F. to 60°F., but at temperatures lower than this the life span is greatly reduced. In temperate zones, house flies pass the winter by a combination of adult hibernation and semi-continuous breeding in protected situations. In addition, house flies extend their range northward during the summer months into areas where they cannot survive the severe winters (Knapp and Knutson, 1958).

BREEDING MEDIA

Almost any type of moist, warm organic material may furnish suitable nourishment for house fly larvae. Animal manure is an excellent breeding medium, accounting for as many as 95% of the house flies in some rural areas. Fresh horse manure may produce as many as 1,200 larvae per pound. Manure of other animals (cows, pigs, rabbits, fowl, etc.) is also very suitable. Accumulations of fowl excrement are commonly infested with larvae, but scattered droppings in dry pens are seldom infested. Human excrement, often loaded with organisms pathogenic to man, is a dangerous source of fly breeding. Breeding occurs in privies, in exposed feces, and in incompletely digested sludge from sewage treatment plants. Garbage is almost always the important source of house flies in urban communities. Fly breeding may be a problem on the premises if garbage is dumped indiscriminately or if it is stored in inadequate containers. Open garbage dumps, too, commonly present in and around our cities, produce large numbers of flies.

ADULT FOOD

The adult house fly is very active, moving about busily from one attractant to another throughout most of the daylight hours. It is strongly attracted to feces and other types of decaying organic material, as well as to milk and foods intended for human consumption. Under natural conditions, house flies seek a wide variety of food substances and thereby obtain a balanced diet. Because of the nature of house flies' mouthparts, their food

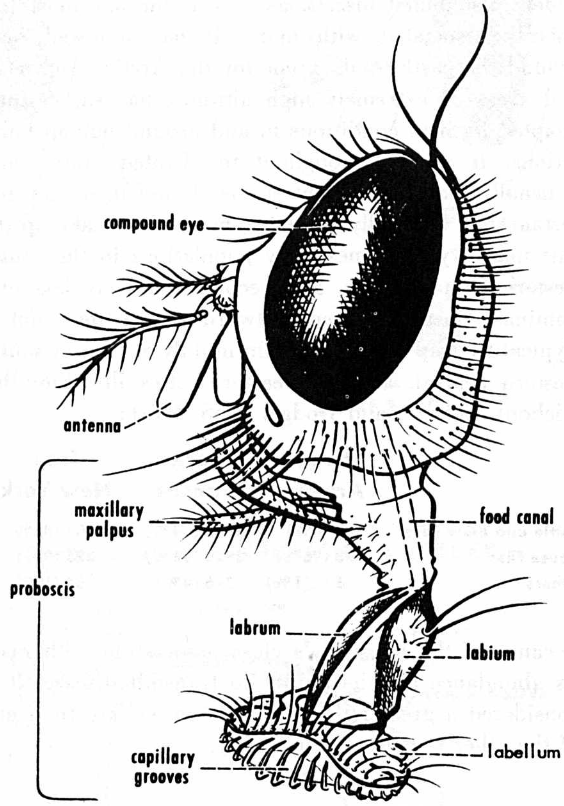


Figure 5.8-A House Fly Mouthparts

must be in the liquid state or must be readily soluble in the salivary and crop secretions. Water is essential and house flies will not ordinarily live more than 48 hours without it. Sugar or starch is necessary for long life, while protein is required for production of eggs. Common sources of food are milk, sugar, blood, meat broth, and many other foods commonly found in and around human habitations. Two or 3 feedings a day are necessary. As the house fly moves about over various items, it periodically regurgitates liquid from the crop and tests the surface with its proboscis, producing light straw-colored spots known as vomit spots. Darker spots which may be observed are fecal spots. Both vomit and fecal spots are commonly found on glass, walls, ceilings, light strings, electric wires, and on other surfaces upon which the flies rest. Accumulations of fly specks are good indicators of habitual resting places of flies.

RESTING PLACES

Flies have certain resting places, showing a strong preference for edges. During the daytime, when not feeding, they rest on floors, walls, ceilings, and other interior surfaces as well as on the ground, fences, steps, privy pits, garbage cans, clotheslines, grass, and herbs outdoors. Flies are essentially inactive at night. They rest indoors, chiefly on ceilings, light strings, and electric wires. They rest outdoors chiefly on fences, electric wires, edges of buildings, weeds and tree branches. These night-time resting places are usually near favored day-time feeding and breeding areas, and are usually protected from the wind. They are typically above ground level, but seldom higher than 15 feet.

FLIGHT

House fly populations can disperse rapidly into new areas by flight. Although house flies cruise at only about 4 miles per hour and wander somewhat aimlessly, they travel as far as six miles (as the crow flies) within 24 hours, and as far as 20 miles, eventually. Flight-range tests using flies tagged with radioactive materials have been performed in a number of different parts of the United States. After releasing the radioactive flies, the scientists set out baited traps in concentric circles around the release point. The majority of the tagged flies recovered were taken within one mile, but a few were taken as far as 20 miles from the point of release (MacLead and Donnelly, 1957).

LONGEVITY

Life span of the adult depends chiefly upon the availability of food and water, and upon temperature. Observations during mid-summer in Texas indicate that, when well fed, flies live 2 to 4 weeks. During cool weather, longevity is prolonged. At Ithaca, New York, adult flies survived 70 days under experimental conditions (Knapp and Knutson, 1958).

TEMPERATURE

Flies are inactive at temperatures below 45°F., and are killed by temperatures slightly below 32°F. Flight begins at about 53°F., and complete activity occurs when air temperatures reach about 70°F. Maximum activity is reached at 90°F., with a rapid decline at higher temperatures until 112°F., which produces paralysis and death (Dakshinamurti, 1948; Siverly, 1958; Thorsteinson, 1958).

HUMIDITY

The effects of humidity are closely related to those of temperature, and it is difficult to assess one without consideration of the other. Lethal effects of both high and low temperatures are more marked when humidity is high. Above 60°F. flies live longest at a relative humidity of 42 to 55 percent. Below 68°F., they are active and long lived. Flies reach a physiological optimum at high temperatures and low humidities. This characteristic correlates with their great abundance in desert areas.

LIGHT

Flies are phototropic (that is, they generally move toward light). The success of the ordinary fly trap depends on this trait. The bait attracts flies to the lower part of the trap, and they are captured when they leave the bait and move upward toward the light. Flies are inactive at night, but will resume activity under artificial illumination. The effects of light on fly activity are closely correlated with those of temperature and humidity.

WIND

Flies are sensitive to strong air currents and are not likely to venture out on extremely windy days. However, some are caught and carried great distances by high winds (such as hurricanes). House flies, probably windborne, have been collected over the ocean more than 100 miles from shore. At lower velocities, flies may travel with the wind or against it. They move upwind toward an attractive odor, fight upwind against moderately strong winds, but move downwind on light breezes not bearing attractive odors.

NATURAL ENEMIES

Organisms which share its environment are of great importance to the house fly. Most of these organisms do no harm, but some act as parasites or predators. Natural enemies of flies include fungi, bacteria, protozoa, round worms, other arthropods, amphibians, reptiles, birds, and certain mammals—particularly man. Fungus infections may assume epizootic proportions, especially at the peak of the fly season, and may become the primary factor limiting fly populations (Steve, 1959).

FACE FLY *(Musca autumnalis)*

In the laboratory, face flies are distinguished from house flies only by minute characteristics (Sabrosky, 1959). However, the habits of these 2 flies are so different, they can be distinguished readily in the field. The face fly, first found in North America (Nova Scotia) in 1952, is now widely distributed in the U.S. and Canada. It is apparently spreading west and south. It also occurs in Europe, Israel, India, and China. Larvae develop in fresh animal excrement, then pupate in soil. Adults, common from early spring to late autumn, hibernate in houses and barns. They suck blood and other exudates from the surfaces of mammals, but cannot pierce the skin. The common name refers to their habit of accumulating on the faces of cattle and other animals, under and around the eyes, in and around the nostrils, and at the lips. In some areas they become important household pests during the winter.

LESSER HOUSE FLIES *(Fannia spp.)*

Lesser house flies (Figure 5.9) are frequently seen hovering in mid-air or flying about the middle of a room. They breed in decaying vegetable and animal matter, particularly in excrement of humans, horses, cows and poultry. The larvae are frequently found in decaying grasses piled up on lawns. The eggs hatch in about 24 hours and the flattened, spiny larvae complete growth in about a week. *Fannia* are of less importance

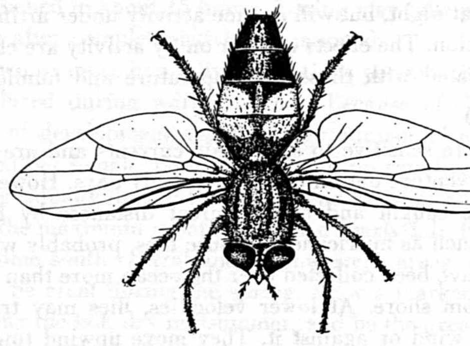


Figure 5.9 **Lesser House Fly (*Fannia canicularis*)**

as household pests or disease vectors than the house fly. There are numerous records of larvae of this genus causing myiasis in man (James, 1947).

STABLE FLY *(Stomoxys calcitrans)*

The stable fly (figure 5.10) is distinguished from all other common domestic flies by its piercing proboscis which protrudes bayonet-like in front of the head. This blood-sucking fly may be found wherever man and his domestic animals occur (Cheng, 1958). It is a vicious biter and attacks a great variety of animals as well as man. It is commonly found around stables and houses.

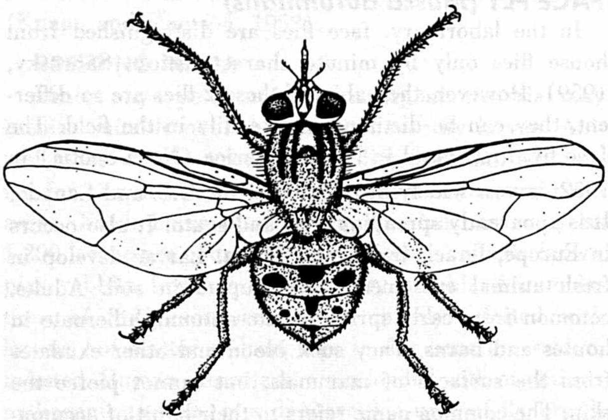


Figure 5.10 **Stable Fly (*Stomoxys calcitrans*)**

The life cycle of the stable fly is similar to that of the house fly except that a longer time is necessary for it to complete its development—the average period being 21 to 25 days. Breeding places are old straw stacks, piles of fermenting weeds, grass, peanut hay, sea weeds, and manure mixed with straw. It breeds very abundantly in piles of marine grasses along the Gulf of Mexico and New Jersey coasts where it becomes a serious pest during the latter part of the summer. The stable fly is not considered an important agent in mechanical transmission of intestinal disease. It does not breed in human excrement, and is not commonly attracted to feces or garbage. It is therefore, less likely to pick up germs of dysentery and other intestinal diseases.

Because of its blood-sucking habits, it has been suspected of transmitting a number of diseases, but there is as yet no proof that it is a biological vector of human disease. However, surra (a trypanosomal disease of horses and mules) and infectious anemia (a virus disease of horses) are transmitted by this species. *Stomoxys calcitrans* causes myiasis of man and of domestic animals (Simmons, 1944; Somme, 1958; Parr, 1959).

HORN FLY *(Haematobia irritans)*

The horn fly has biting mouthparts (figure 5.6) similar to those of the stable fly, but is not a "domestic" species. It is a pasture and range fly about one-half the size of the stable fly. It is primarily a pest of cattle, clustering at the base of the horns and feeding there. It often produces serious blood loss, weakness, and restlessness. It rarely bites man, although the senior author once witnessed a total disruption of pipeline laying as a result of attacks by these flies. Eggs are laid in fresh cow dung. Pupation occurs in the ground.

FALSE STABLE FLIES *(Muscina spp.)*

False stable flies (figure 5.11) breed in decaying animal and vegetable matter, and are commonly found in scattered garbage. The larvae become carnivorous as

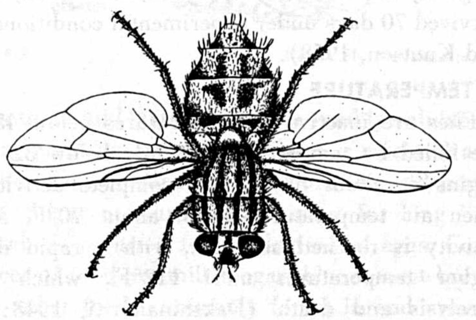


Figure 5.11 **False Stable Fly (*Muscina stabulans*)**

they near maturity and destroy other fly larvae which they encounter. Larval development requires 15 to 25 days. The adult fly enters houses frequently and is attracted to human foods, including meat, fruit, and vegetables. It is a vector of intestinal disease organisms, and there are reports of cases of human intestinal myiasis which probably resulted from ingesting food containing eggs of *Muscina*.

TSETSE FLIES *(Glossina spp.)*

Tsetse flies (figure 5.12) of tropical and subtropical

Africa are one of the insect groups of the greatest public health importance. By carrying African sleeping sickness to man, and nagana to cattle and sheep, these

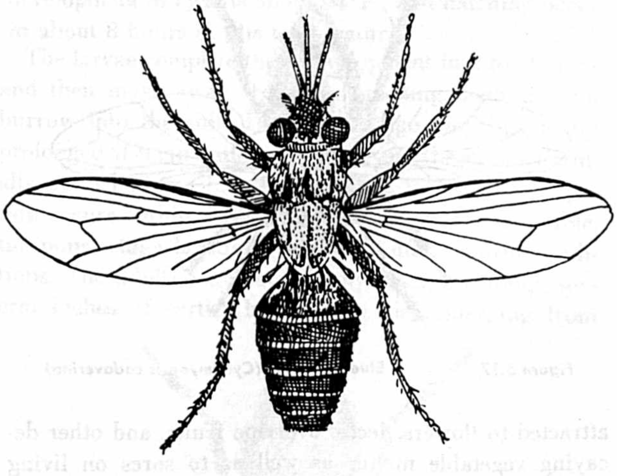


Figure 5.12 Tsetse Fly *(Glossina palpalis)*

biting flies have prevented humans from utilizing large areas of superior agricultural land, and have brought disease and death to millions of hoofed animals. These flies are closely related to the stable fly, and much research is being done on methods of controlling them.

DUMP FLIES *(Ophyra spp.)*

Dump flies (figure 5.13) are widely distributed and are frequently very abundant in urban communities. At times they may be the principal species around garbage disposal areas. *Ophyra* do not enter houses to any great

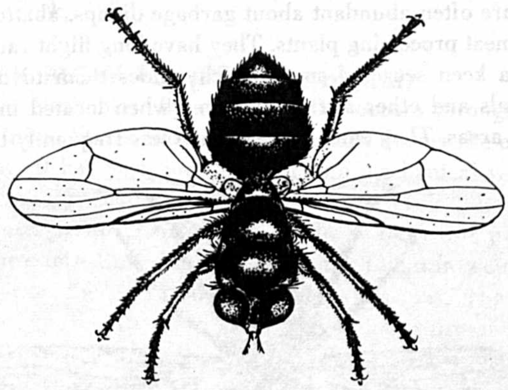


Figure 5.13 Dump Fly *(Ophyra leucostona)*

extent, but in the Pacific Northwest they may be numerous in restaurants where, in some cases, they replace the house fly as the predominant species. The biology of dump flies is not well known. Larvae are found in mixed garbage and in fowl excrement. They are believed to be predaceous upon other fly larvae.

FLESH FLIES (Sarcophagidae)

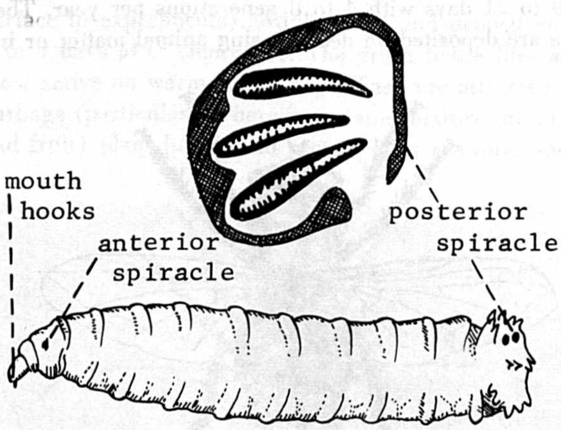


Figure 5.14 Flesh Fly *(Sarcophaga haemorrhoidalis)*

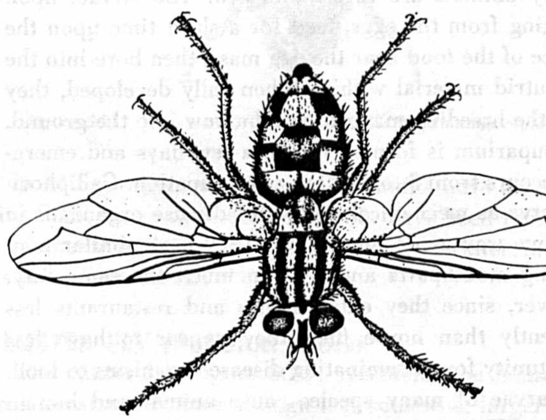


Figure 5.15 Flesh Fly *(Sarcophagula occidua)*

The family Sarcophagidae includes a great number of species (figures 5.14 and 5.15). They are commonly referred to as flesh flies because the larvae of most species breed in meat. Some breed prolifically in animal excrement, especially in dog stools. They differ from other domestic flies in that the females deposit living larvae rather than eggs. Flesh flies are often very abundant in urban communities, but do not ordinarily enter houses or restaurants. They do not appear to be of much importance as mechanical vectors of human disease, nor are they often of much nuisance importance. They cause human myiasis, particularly intestinal myiasis.

BOTTLE FLIES AND BLOW FLIES (Calliphoridae)

These flies deposit eggs upon animal carcasses and meat products causing them to "bottle" or be "blown" with maggots. They are common in most urban areas and are often abundant about garbage dumps, abattoirs, and meat processing plants. They have long flight ranges and a keen sense of smell which guides them to dead animals and other attractants, even when located in remote areas. They enter houses much less frequently than

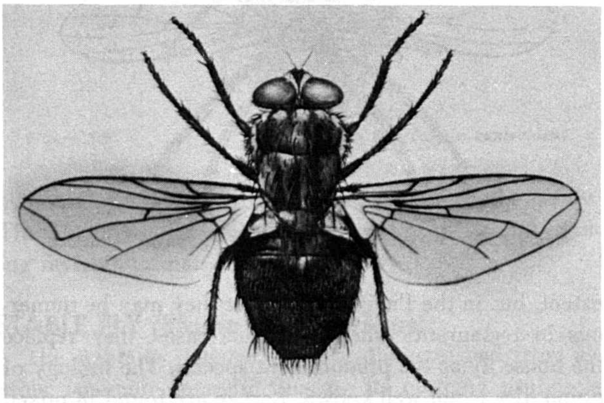


Figure 5.16 Blue Bottle Fly *(Calliphora vicina)*

house flies. The developmental stages are the same as for the house fly. Although they usually deposit their eggs upon meat, they will oviposit upon a wide range of fresh and decaying plant refuse if meat is not present. Eggs may be deposited on living animals, although clean, healthy animals are rarely attacked. The larvae, upon emerging from the eggs, feed for a short time upon the surface of the food near the egg mass, then bore into the less putrid material within. When fully developed, they leave the breeding material and burrow into the ground. The puparium is formed within a few days and emergence occurs from 3 to 20 days after pupation. Calliphoridae serve as mechanical vectors of disease organisms in the same way as do house flies. They have similar nonpiercing mouthparts and feed in much the same way. However, since they enter homes and restaurants less frequently than house flies, they appear to have less opportunity for disseminating disease organisms to food. The larvae of many species cause animal and human myiasis (Hall, 1948).

BLUE BOTTLE FLIES
(Cynomyopsis cadaverina and *Calliphora)*

Blue bottle flies (figures 5.16 and 5.17) require 15 to 20 days or more to develop from egg to adult. The adults commonly enter homes during the cooler seasons. They frequent places where meat is exposed and may be abundant about slaughter houses. The adult flies are

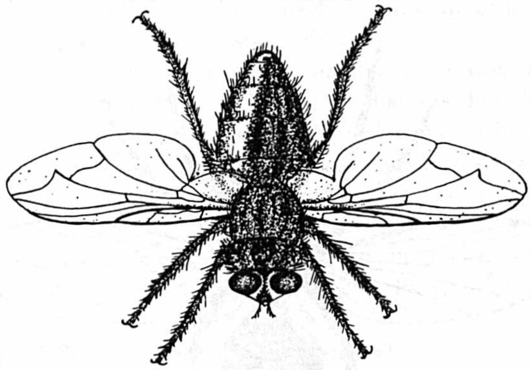


Figure 5.17 Blue Bottle Fly *(Cynomyopsis cadaverina)*

attracted to flowers, feces, overripe fruits, and other decaying vegetable matter as well as to sores on living animals and may cause intestinal myiasis (Scott, 1962).

GREEN BOTTLE FLIES AND BRONZE BOTTLE FLY (*Phaenicia spp.* and others)

Green and bronze bottle flies (figures 5.18, 5.19 and 5.20) occur throughout the United States and are frequently the most abundant of the Calliphoridae. The group includes the genera *Phaenicia, Lucilia,* and *Bufolucilia* as well as several less common genera. The species most commonly found around man are *Phaenicia cuprina* (the bronze bottle fly), and *Phaenicia sericata* (the green bottle fly). The life cycle is normally completed in 9 to 21 days with 4 to 8 generations per year. The eggs are deposited on decomposing animal matter or in

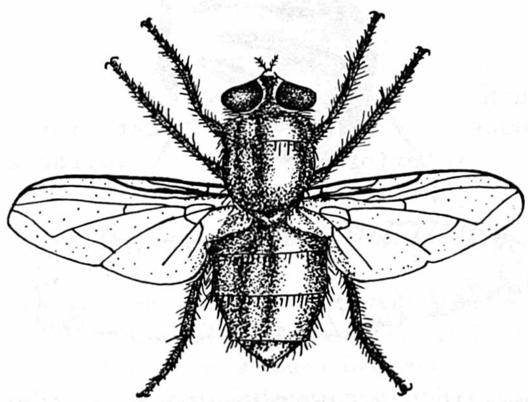


Figure 5.18 Green Bottle Fly *(Phaenicia sericata)*

garbage containing mixtures of animal and vegetable matter. Females are strongly attracted to flesh and oviposition begins within a few hours after death of an animal. Fresh meat is often attacked within a few minutes after exposure. They also deposit eggs on wounds and occasionally cause intestinal myiasis (Scott, 1962). The average number of eggs produced at one time is about 180, although single females have been reported to deposit over 2,000. The optimum temperature for development of eggs is about 94°F., and hatching occurs in about 8 hours at this temperature.

The larvae complete their development in 2 to 10 days and then move away from the breeding medium, and burrow into the soil. The larval stage may be greatly prolonged if temperatures are low, and these flies normally overwinter as full grown larvae in the soil. Pupation occurs within 3 days if temperatures are favorable, the pupal stage lasting 3 to 6 days under warm conditions. The adults may successfully emerge through several inches of earth (half of the flies emerging from puparia buried under 3 feet of loose soil reached the surface in experiments). Adults mate and deposit eggs 5 to 9 days after emergence. The green bottle flies are most active on warm sunny days. They are attracted to garbage (particularly where it contains mixtures of meat and fruit) plant juices, and nectar. They are often seen in large numbers on shrubbery, leaves of cucumbers and other melons, and on other plants. At times, particularly in the spring and fall, they enter houses and restaurants, where they usually attract attention because of their shiny green or coppery color, and their buzzing flight. They may fly 10 miles from their breeding places within a few days. Favored night-time resting places include trees, bushes, and sides of buildings (Wallace and Clark, 1959).

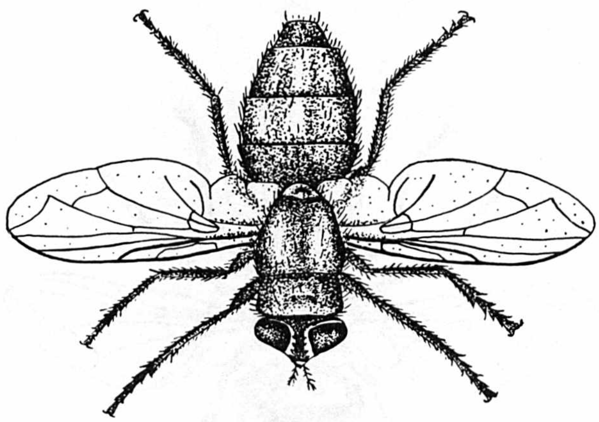


Figure 5.19 Bronze Bottle Fly *(Phaenicia cuprina)*

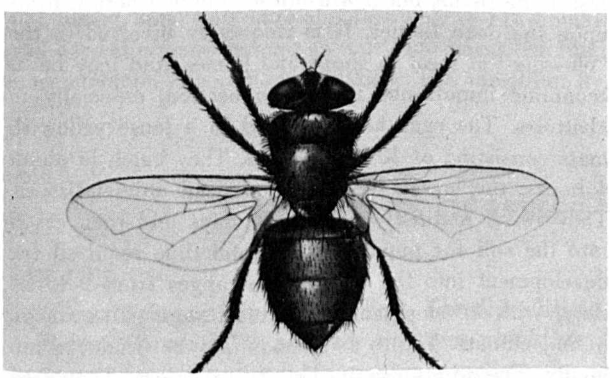


Figure 5.20 Green Bottle Fly *(Lucilia illustris)*

BLACK BLOW FLY *(Phormia regina)*

The black blow fly (figure 5.21) occurs throughout the United States and is most abundant during the early spring. It has been incriminated as a mechanical vector of dysentery and diarrhea (Knuckles, 1959). It is a common producer of myiasis in sheep and cattle in the southwestern United States where it is found in wounds, castration incisions, and dehorning incisions. The life cycle requires 10 to 25 days and is generally similar to that of the green bottle flies. The eggs are usually deposited in masses on animal carcasses or in the edges of wounds of living animals. Larvae may occur in great number in animal carcasses or in the paunch contents of slaughtered animals. They also breed abundantly in garbage. The larval stage requires 4 to 15 days, the pupal stage 3 to 13 days and the adults begin depositing eggs 7 to 17 days after emergence. The adults have an effective flight range of 6 to 10 miles but have been reported to disperse as far as 28 miles. They overwinter in soil as full grown larvae.

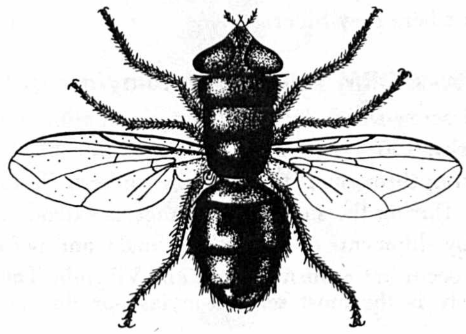


Figure 5.21 Black Blow Fly *(Phormia regina)*

CLUSTER FLY *(Pollenia rudis)*

The cluster fly (figure 5.22) resembles the house fly in general appearance, though it is somewhat larger and darker. The thorax is covered with thick, yellowish crinkly hair. It is distributed throughout most of the Northern Hemisphere, being most common in the northern United States. The eggs are deposited in the soil in a rather indiscriminate manner. They hatch in about 3 days, and the larvae enter the bodies of earthworms upon which they feed for about 13 days. They then leave the host, pupate in the soil, and emerge as adults about 2 weeks later. There are probably 4 generations a year in the United States. Cluster flies accumulate in swarms in closets, attics, and unused rooms. They may be concentrated on open ceilings or walls, or may crawl behind

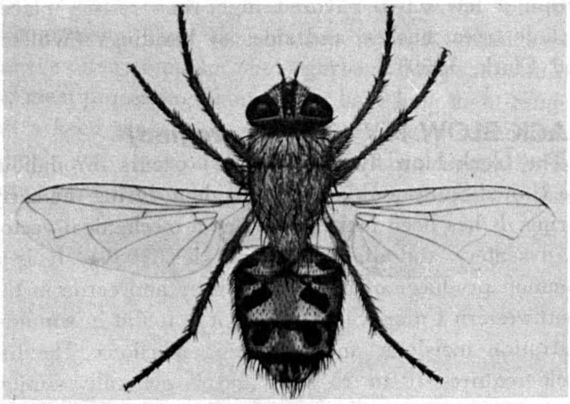


Figure 5.22 Cluster Fly *(Pollenia rudis)*

window casings, mouldings, loose wallpaper, plaster, pictures, or furniture. During mild weather in the winter or early spring they move about sluggishly, thus attracting attention to their presence. They are not of direct public health importance, but may become a nuisance in houses where they hibernate.

SCREW-WORM FLIES *(Cochliomyia spp.)*

The screw-worm fly, *Cochliomyia hominivorax* (see Sabrosky, 1962) (figure 5.23) is a semitropical species occurring throughout the year in southern Florida and Texas. During the summer, its range is extended northward by shipments of domestic animals, and before fall, it may occur in California, Iowa, and Virginia. The screw-worm fly is the most serious myiasis-producing fly in

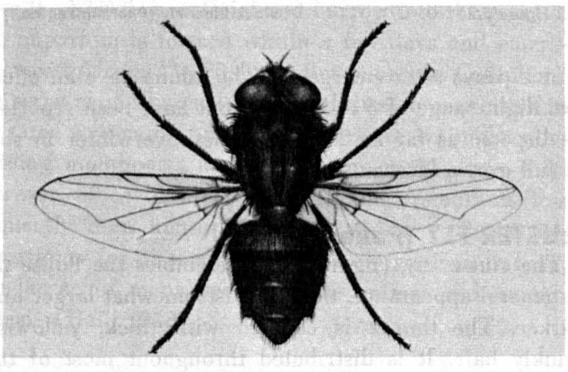


Figure 5.23 Screw-Worm *(Cochliomyia hominivorax)*

the United States. It is strictly parasitic, attacking only fresh clean wounds. It parasitizes cattle, sheep, goats, man, and other animals. Infestation of 20 percent of the livestock has been reported in some areas, with mortality reaching 20 percent of those infested. In 1935 there were 1,200,000 cases in livestock and 55 cases in man in Texas alone. The eggs of the primary screw-worm fly are glued in oval masses of 10 to 400 each to dry tissues near the surface of wounds. They hatch in 11 to 21 hours and the larvae penetrate the tissues, leaving their posterior ends exposed to the outer air. Feeding is completed in 4 to 8 days, after which they drop to the ground and enter the soil to pupate. The average life cycle under summer conditions requires 24 days. Adults seem to be less active than the other Calliphoridae, but they have a recorded flight range of 9 miles (Knipling, 1960).

The secondary screw-worm fly, *Cochliomyia macellaria* (figure 5.24) is very similar to the screw-worm in appearance. It occurs throughout the United States, but is

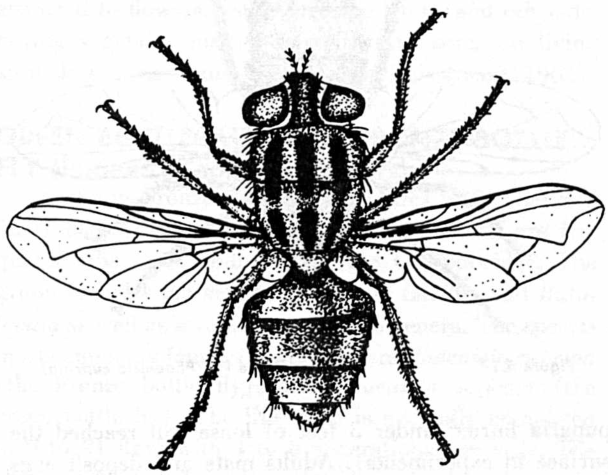


Figure 5.24 Secondary Screw-Worm *(Cochliomyia macellaria)*

seldom abundant in the north. This species does not infest living tissue, but it will infest wounds where it feeds upon the dead tissues. It is frequently involved in the "blowing" of meat in shops and homes, and may be of economic importance in this connection, especially in abattoirs. The eggs are deposited in a loose yellowish mass consisting of 40 to 250 eggs. They hatch in about 4 hours, the larvae feeding upon dead animal tissues. They reach maturity in 6 to 20 days and then crawl into the soil for pupation. The total time required for development into the adult stage ranges from 9 to 39 days, with development being most rapid in a warm, humid climate. Ten to 14 broods may be produced annually. The adults usually live 2 to 6 weeks. They feed on a variety of foods, from garbage to nectar. Dead animals and vegetation surrounding them may swarm with thousands of these flies. A maximum flight range of 15 miles has been recorded.

BOT FLIES

(Oestridae, Cuterebridae, Gasterophilidae)

Bot fly larvae cause myiasis in many kinds of domestic animals and in man. These flies are in 3 different families, but the more important species may be discussed together (figure 5.25). The human bot fly, *Dermatobia hominis,* occurs in South and Central America, and in Mexico. Its larvae parasitize birds and mammals, including man. The adult fly does not seek its host directly,

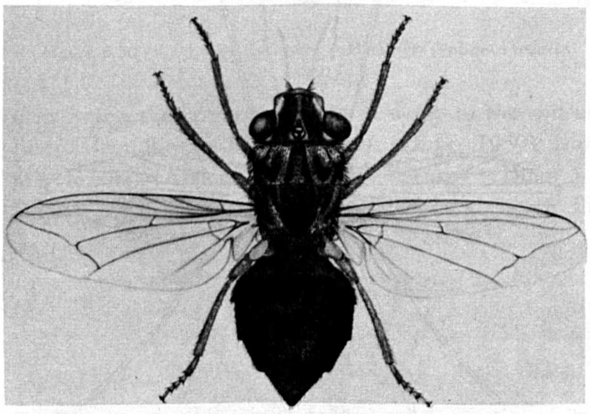


Figure 5.25 **Human Bot Fly *(Dermatobia hominis)***

but uses as a vector some other species of insect or arachnid (as *Psorophora* mosquitoes, domestic flies, and ticks). The female captures a vector species, glues 15 to 25 eggs to it, and then releases it. When the vector alights on a warm-blooded animal, the eggs hatch and larvae penetrate the skin. Development requires from 50 to 100 days after which larvae extricate themselves, drop to the ground, and pupate. The rabbit and rodent bots, *Cuterebra spp.*, are able to cause nasal and dermal myiasis in man as well as to parasitize their more common hosts (Penner, 1958). The sheep bot fly, *Oestrus ovis,* usually causes nasal myiasis in sheep, but may cause myiasis of the human eye (Atlas, *et al.*, 1960). It is world-wide in distribution. The head bot fly of horses and asses, *Rhinoestrus pupureus,* has a life cycle similar to *Oestrus ovis,* and may also cause myiasis of the human eye. It is known from Africa, Europe, and Asia. The cattle bot flies or ox-warbles, *Hypoderma spp.*, are usually found in tumorous swellings on the backs of cattle, but may cause myiasis in horses and man. The larvae of horse bot flies, *Gasterophilus spp.*, usually live in the alimentary tracts of horses, asses, and related hosts. After completing development, they pass out with the feces, pupate, and the adults emerge. The adult female fastens her eggs to the hair or lips of a host animal.

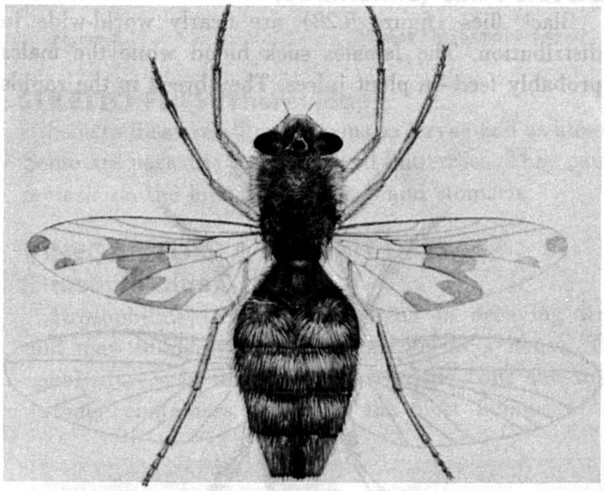


Figure 5.26 **Horse Bot Fly *(Gasterophilus intestinalis)***

The larvae are either swallowed, or they burrow under the skin, eventually reaching the alimentary canal where they fasten to the mucosa by means of their mouth hooks.

SOME FLIES OF LESSER PUBLIC HEALTH IMPORTANCE

MIDGES

(Ceratopogonidae, Heleidae, Tendipedidae, Chironomidae)

Midges (figure 5.27) are very tiny flies which breed in water or soil. Tendipedid larvae are sometimes found in water reservoirs, and many a homemaker has been "shaken" when she found "worms" in her glass of water. The tendipedid midges do not bite, but the heleids, particularly *Culicoides spp.*, are vicious biters. They are so tiny that the victim cannot usually figure out what is biting him. These biting midges are sometimes called "no-see-ums". *Culicoides spp.*, transmit two types of human filariasis (caused by *Mansonella ozzardi* and *Acanthocheilonema perstans*). They are also vectors of ephemeral fever of cattle, bluetongue of sheep, onchocerciasis cervicalis of horses and mules,

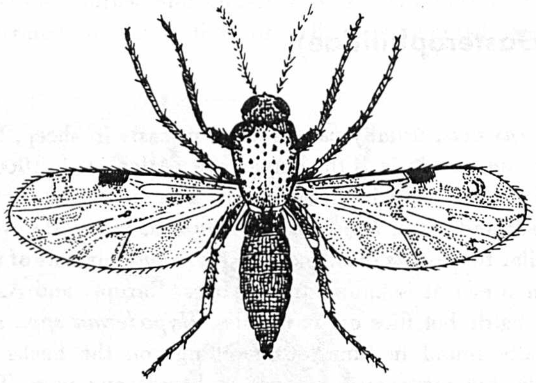


Figure 5.27 **Biting Midge (*Culicoides furens*)**

and onchocerciasis gibsoni of cattle and zebus (Foote and Pratt, 1954).

BLACK FLIES (Simuliidae)

Black flies (figure 5.28) are nearly world-wide in distribution. The females suck blood while the males probably feed on plant juices. They breed in the rapids

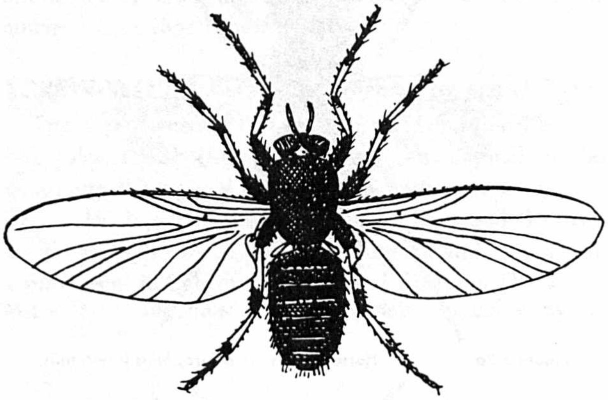


Figure 5.28 **Black Fly (*Simulium venustum*)**

of clear water streams, the larvae and pupae clinging to the rocks. One of the wonders of the biological world is the emergence of black flies from the fast moving water into the air. Black fly bites are painless at first, but later become swollen and painful. Large swarms can kill an animal rapidly. Several species transmit onchocerciasis (blinding filariasis) to man while at least one (*Simulium decorum*) is a mechanical vector of tularemia (Dalmat, 1955; Duke and Beesley, 1958).

SAND FLIES, FILTER FLIES AND MOTH FLIES (Psychodidae)

Psychodids (figure 5.29) are common around human habitations. They breed in decomposing organic materials such as grass, plant litter, sewage (Hawkes, 1959) and garbage. Some common sources of domestic infestations are dirty garbage containers, water traps in plumbing fixtures, and accumulated debris around the edge of sinks and wash basins built into counter tops. In the Near and Far East, North Africa, and South America, sand flies (*Phlebotomus spp.*) bite and transmit sandfly fever, several types of leishmaniasis (Pringle, 1956 and 1957) and bartonellosis. Filter flies (*Psychoda spp.*) are a serious problem at many sewage

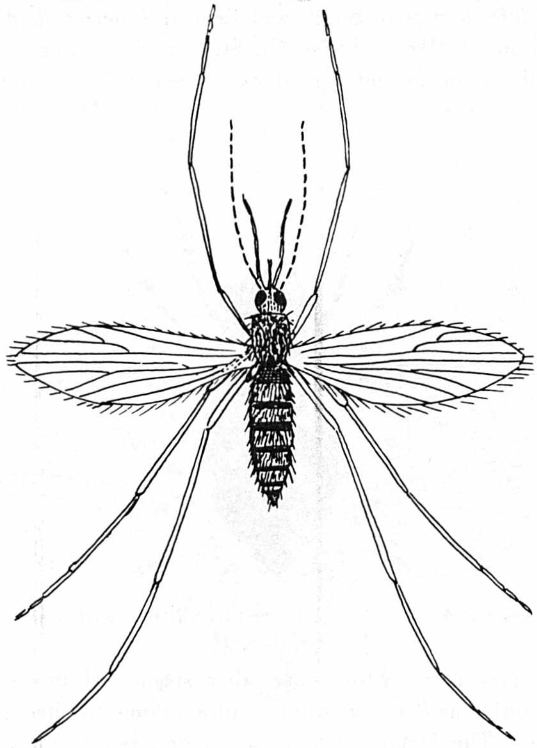


Figure 5.29 **Sand Fly (*Phlebotomus*)**

treatment plants. Psychodidae may cause myiasis in man (Adler and Theodor, 1957; Fairchild, 1955; and Quate, 1955 and Scott, 1961b).

CRANE FLIES (Tipulidae)

Crane flies are slender, long-legged flies which breed in water, moss, mud, sand or soil. They cause intestinal myiasis in man.

NET-WINGED MIDGES (Blepharoceridae)

Net-winged midges look like mosquitoes and may be found on shrubs and trees along mountain streams and near waterfalls. They breed in the rapidly moving water much like black flies. Females of some species bite man.

DEER FLIES, HORSE FLIES, AND RELATED FORMS (Tabanidae)

Tabanids (figure 5.31) are found in nearly all parts of the world and the females of all species suck blood. Many are vicious biters and can inflict painful injury to man. Male tabanids take plant juice or the body juices of other insects. Most species deposit their eggs

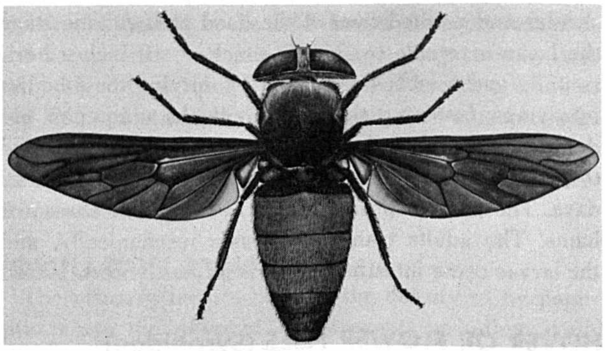


Figure 5.30 Horse Fly *(Tabanus atratus)*

near water, the larvae maturing in damp to wet soil and litter. Deer flies (*Chrysops spp.*) (Duke, 1959) transmit loiasis (African eye-worm disease) (Duke and Wijers, 1958) while both deer flies and horse flies

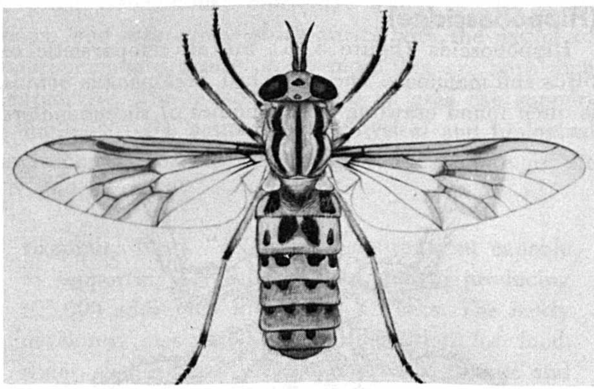


Figure 5.31 Deer Fly *(Chrysops discalis)*

(*Tabanus spp.*) serve as mechanical vectors of anthrax and tularemia (Philip, 1947; Beesley, 1958; Thorsteinson, 1958).

SNIPE FLIES (Rhagionidae)

Snipe flies (figure 5.32) breed in water or soil. Their larvae are predaceous. Members of the genera, *Atherix, Rhagio, Spaniopsis,* and *Symphoromyia* bite man. They have not been shown to be the vectors of any human disease.

WINDOW GNATS (Sylvicolidae)

Window gnats breed in decaying organic materials and may cause intestinal myiasis in man.

SOLDIER FLIES (Stratiomyidae)

Soldier flies breed in decaying organic materials and may cause intestinal myiasis in man. These flies may be an important check on populations of domestic flies since the larvae are predaceous on common domestic fly larvae (Furman, *et. al.,* 1959).

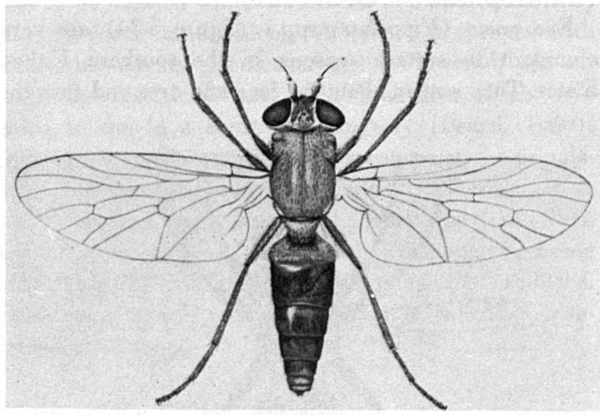


Figure 5.32 Snipe Fly *(Symphoromyia)*

STILETTO FLIES (Therevidae)

Stiletto flies are all predaceous as larvae and as adults. Some are parasitic on moths and butterflies. They cause myiasis on the human esophagus and stomach.

VINEGAR FLIES AND FRUIT FLIES (Drosophilidae)

Drosophilids (figure 5.33) breed in decaying fruit and may suddenly become numerous in a house. The usual sources in the home are overripe fruit and dirty garbage containers. Probably the most famous of all

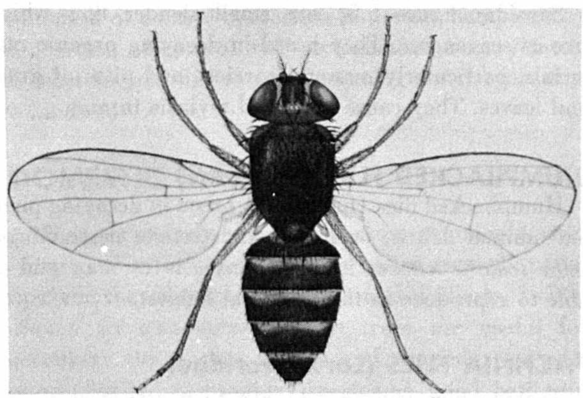


Figure 5.33 Fruit Fly *(Drosophila repleta)*

laboratory animals belongs to this family—*Drosophila melanogaster*—upon which our knowledge of genetics is based. Members of the genus *Drosophila* cause intestinal myiasis in man (Dorsey and Carson, 1956; and Pimentel, 1955).

TYLID FLIES (Tylidae-Micropezidae)

Tylids are rare in North America, but the larvae of *Calobata spp.*, (*Trepidaria spp.*) cause intestinal myiasis in man.

EYE GNATS AND RELATED FORMS RMS (Chloropidae = Oscinidae)

Eye gnats (*Hippelates spp.*) (figure 5.34) are very abundant in certain seasons in the southern United States. They swarm about the face and eyes and rasp the

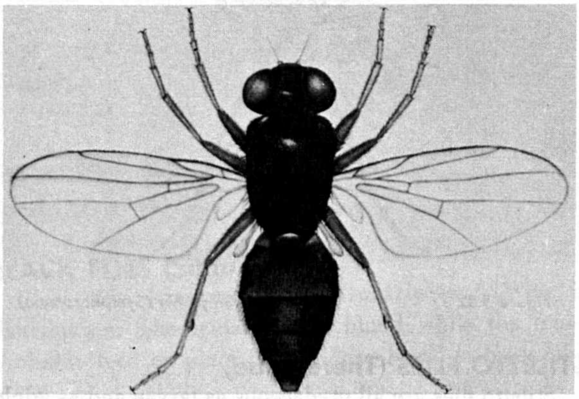


Figure 5.34 Eye Gnat (*Hippelates pusio*)

eye membranes with their mouthparts. They transmit conjunctivitis, yaws, and trachoma. Larval development occurs in loose soil in which there is considerable organic material. The life cycle is completed in from 2 to 4 weeks.

SEPSID FLIES (Sepsidae)

Sepsids (figure 5.5) are small slender flies which live as scavengers. They breed in decaying organic materials, particularly manure, carrion, and piles of grass and leaves. They cause intestinal myiasis in man.

HUMPBACKED FLIES (Phoridae)

Humpbacked flies (figure 5.4) breed in decaying plant and animal debris, or in ant and termite nests. *Megaselia scalaris* causes intestinal myiasis in man and is able to reproduce in the intestinal habitat.

TACHNIA FLIES (Larvaevoridae)

Tachina flies (figure 5.4) are all parasitic as larvae, mostly on other insects. They resemble the Sarcophagidae (flesh flies) and are often mistaken for them. They are used in the biological control of some insects of agricultural importance, particularly of moths and butterflies. Although they may be present in great numbers around humans, they have not been shown to be associated with any human disease.

CHEESE MAGGOT AND RELATED FORMS (Piophilidae)

The cheese skipper or maggot, *Piophila casei* (figure 5.5) is about the size of the house fly. The larvae are slender and pointed toward the head end. At one stage the larvae are able to skip as much as 10 inches horizontally and 6 inches vertically, by curving their bodies into rings, fastening their mouth hooks onto their abdomens, suddenly releasing their holds, and throwing themselves into the air. The life cycle requires about 12 days. The adult deposits 140 to 500 eggs on cheese or hams. The adults transmit diseases mechanically, and the larvae cause intestinal myiasis in man (Scott, 1962).

HOVER OR FLOWER FLIES (Syrphidae)

Syrphids (figure 5.4) resemble bees in the adult stage. The larvae breed in highly polluted water and have long breathing tubes which have caused them to be called "rat-tailed maggots" (figure 5.6). Members of the genera *Tubifera* and *Helophilus* cause human intestinal myiasis.

SHEEP KED AND LOUSE FLIES (Hippoboscidae)

Hippoboscids (figure 5.35) are all ectoparasitic on birds and mammals. The sheep ked, *Melophagus ovinus*, is often found crawling on the bodies of sheephandlers,

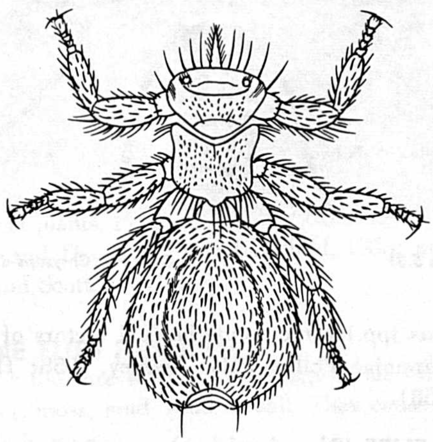


Figure 5.35 Sheep Ked (*Melophagus ovinus*)

and may inflict a painful bite. It is suspected of being a vector of Q fever in Canada (Pavilanis, 1959). Bird louse flies, such as *Pseudolynchia canariensis* from the pigeon may also be found on and biting man. (Scott, 1961a).

SHORE FLIES (Ephydridae)

Shore flies (figure 5.4) are found in moist places. *Teichomyza fusca* from Europe and South America causes urinary myiasis in man.

FLY SURVEY TECHNIQUES

The effectiveness of fly control operations may be indicated by public reaction, but the only reliable index is an actual fly count in the field. Information on the needs and accomplishments of a fly control program may best be obtained by careful measurement of breeding sources, and fly populations both before and after control work. Effective survey and control operations depend to a great extent upon a thorough knowledge of fly population dynamics.

POPULATION DYNAMICS

The primary factors limiting the density of fly populations are the *physical environment*, including availability of food, water, shelter, and suitable breeding media (Lewontin, 1957); *parasitism* by viruses, rickettsiae, spirochaetes, bacteria, fungi, protozoa, and roundworms; *predation* by centipedes, mites, spiders, pseudoscorpions, other insects, amphibians, reptiles, birds, and mammals—especially man; and *competition* of one fly with another for the benefits of the environment.

Fly populations are modified by *reproduction*, which is often tremendous; *mortality*, which is also enormous; and *migration*, which varies with the nature of environmental pressure. Many more flies are born than can survive. The numbers of flies an area can support is limited by the nature of the physical and biological environment. Excess flies must either migrate or die (Nicholson, 1957).

Example: Block "A" has an environment capable of supporting 1,000 house flies, and of producing 125,000 additional flies every 2 weeks. The newly developed flies face severe competition for food, water, shelter. They are slaughtered by disease and predation. Some migrate and compete with neighboring fly populations. The small percentage surviving, mate; and the females compete for suitable media in which to lay their eggs. Another 125,000 eggs hatch and the great struggle begins anew.

Many fly control measures tend to kill only that excess of population which would die in a short time anyway. If, for instance, Block "A" above is sprayed with insecticide the fly population will be lowered, but actually the insecticide only kills those flies which were going to die in a short time anyway (Beard, 1960). Individuals surviving will soon reconstruct the population. Long term fly control for block "A" must either remove enough food, water and shelter that fewer than 1,000 flies can survive, or must remove enough breeding material that fewer than 1,000 flies can be produced. This "long term" control technique is called *environmental sanitation.*

APPRAISAL TECHNIQUES

Fly surveys are made to determine *what kinds* of flies and *how many* flies are present in an area. By looking up the ecology of common species in reference literature, personnel determine what larval habitats should be searched out and eliminated. By comparison of successive surveys they evaluate control effectiveness. Since it is not practical to determine the precise number of flies, surveys are designed to give an *index* of the population. A good survey will also show relative numbers of the various species. The method used must be reliable enough that different surveys will be comparable. Reliability is limited by the skill of the surveyor, the errors that are inherent in the methods, and fluctuations of fly populations in response to environment. Evaluation of control operations is greatly hampered by the coaction of control and environment. Survey methods must be modified to suit the ecology of the flies that are involved.

SURVEY METHODS FOR DOMESTIC FLIES

Flies of the families Muscidae, Sarcophagidae, Calliphoridae, Drosophilidae, Larvaevoridae, Sylvicolidae, Stratiomyidae, and Syrphidae are usually considered to be domestic flies. With all these, *adult surveys* are usually more practical and reliable than *larval surveys.* Consequently, all commonly employed techniques are related to adult populations (Schoof, 1955).

FLY TRAP SURVEYS

Trap surveys have the advantages of securing a reasonable cross section of the population for careful identification; securing an approximate count of the relative numbers of the various species; and trapping flies alive for laboratory study. The three most commonly used fly trap survey techniques are the baited trap, fly paper strips, and the cone trap (Mallison and Williams, 1958).

Baited fly trap surveys. Bait traps are useful for determining the species present and, roughly, the relative numbers of the various species. A good bait trap (figure 5.39) is durable, attractive, easily used, and has some device for fastening it to the ground. A suitable sign such as "Do Not Touch, Health Department Test" should be attached. An attractant is placed in the pan under the trap. After feeding or depositing eggs on the bait, the flies move upward toward the light, and enter the trap through the small opening in the cone. Since

FLY GRILL RECORD

TOWN & STATE: SECTION: BLOCK #: DATE: HOUR:

GRILL READINGS	Tabulate the five highest counts										
	1	2	3	4	5	6	7	8	9	10	
ATTRACTANTS											TOTALS
HOUSE FLY *Musca domestica*											
FLESH FLIES *Sarcophaga* spp.											
LESSER HOUSE FLIES *Fannia* spp.											
STABLE FLY *Stomoxys calcitrans*											
FALSE STABLE FLIES *Muscina* spp.											
BLUE BOTTLE FLIES *Calliphora* & *Cynomyopsis* spp.											
DUMP FLIES *Ophyra* spp.											
SECONDARY SCREW WORM FLY *Cochliomyia macellaria*											
BLACK BLOW FLY *Phormia regina*											
GREEN BOTTLE FLY *Phaenicia sericata*											
BRONZE BOTTLE FLY *Phaenicia cuprina*											
OTHERS											
TOTALS											

BLOCK AVERAGE: HIGH COUNT: INSPECTOR:

HIGH COUNT: The highest count of the five high grill readings.

BLOCK AVERAGE: Total the five high grill readings and divide by five.

ATTRACTANTS:

A. Garbage (mixed)
B. Excrement
C. Fruits
D. Vegetables
E. Dish water
F. Dead animals
G. Seafood wastes
H. Feeds
I. Bones
J. Decaying vegetation
K. Other

Figure 5.36

they do not generally fly downward to escape, and since the cone opening is difficult to find, few escape. Not all flies respond to the same attractant so an all-purpose bait is used: fish heads, chicken entrails, vegetables, and fruit. Traps are placed in different sections and in different types of blocks (slums, good housing, business, industrial, etc.). Flies are killed in chloroform jars, then identified and counted. Collections may be stored in boxes, such as ice cream cartons. Each collection should be labelled with date, location, method of collection, and name of collector. In extensive surveys a special form may be designed for recording data.

Fly paper strip surveys. Strip surveys are rapid, but the data obtained have little numerical reliability. Only a few kinds of flies present will be captured. Strips of sticky paper are suspended in buildings and out-of-doors for a definite period of time (usually 4 hours) after which flies are collected, identified, and counted.

Fly Cone Surveys. Fly cones are superior to baited traps and fly paper strips because they make use of many different natural attractants, instead of depending upon standard introduced attractants. The fly cone (figure 5.37) made of screen wire, is placed over a natural attractant (garbage, manure, etc.) trapping flies beneath it. A dark cloth is thrown around the cone and the apparatus is carefully agitated. Attempting to escape, the flies move upward toward the light and enter the cage; then, the sliding door of the cage is closed and the collection is labeled. Flies may be taken to the laboratory for bacteriological and virological study.

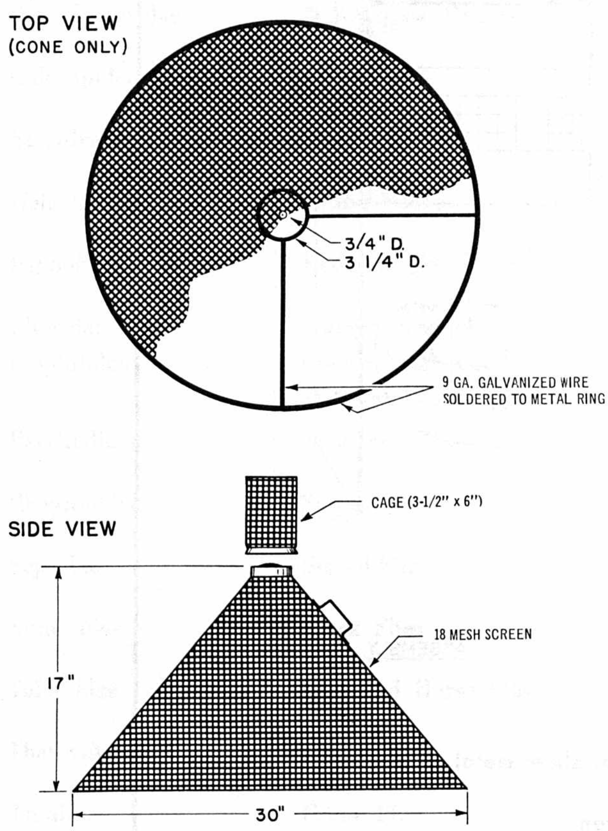


Figure 5.37 Fly Cone

FLY GRILL SURVEYS

Fly grills are widely used in modern evaluation of fly populations. They are faster than baited trap or fly cone surveys and give a highly valid picture of the fly situation. The fly grill depends upon the tendency of flies to rest on edges, and so it presents many attractive resting sites. The grill (figure 5.38) is placed over natural attractants (garbage, manure, etc.) and the number of flies landing on the grill during a 30 second interval is tabulated. When the grill is put down, the flies are somewhat disturbed and fly upward a short distance. When all is again quiet, they come back down, alighting on the grill instead of the attractant. Record is made of the total number of flies and of the number of individuals of each species present. Use of the grill requires a high degree of familiarity with the species present. Consequently, flies must be trapped and sorted by the surveyor until he is able to recognize all common species instantly. If fly counts are so high that total counts become impractical, the grill may be divided into halves, quarters, or sixths, with painted markings. At least one-sixth of the grill must be counted. A minimum of 10 counts is made in each block sampled, and the 5 highest counts are recorded on the grill record (figure 5.36).

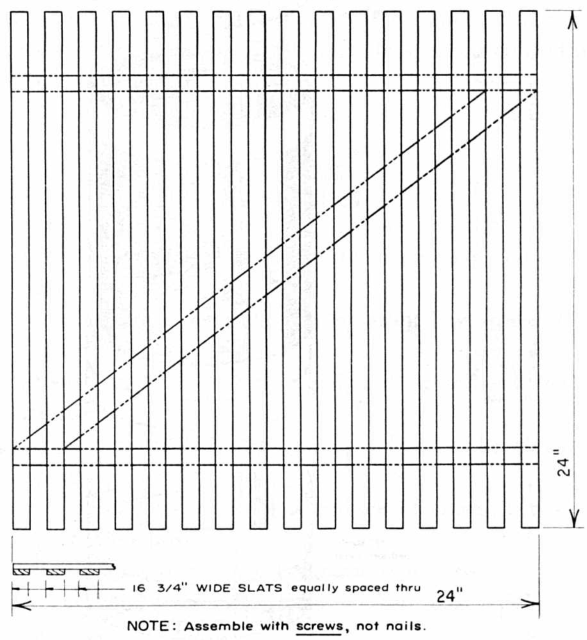
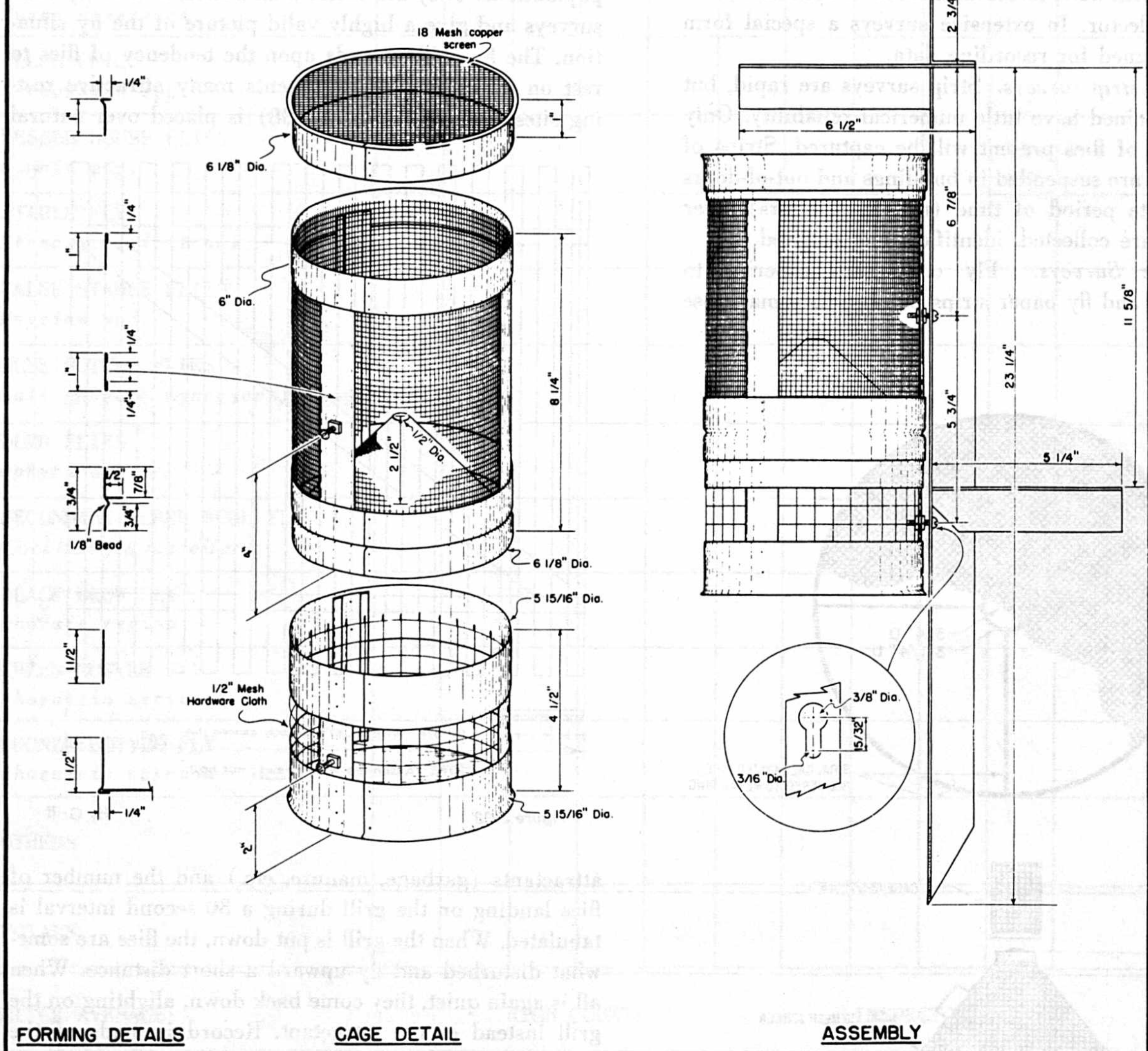


Figure 5.38 Fly Grill



Bands and vertical members: 24 ga. sheet metal
Stand: 1¼" x 1¼" Angle iron
Carrying Handle: 1/8" x 1" strap iron
Bolts: 1/8" x 3/4" stove bolts
Spot well all bands, solder all screen and hardware cloth

Bait Trap

Figure 5.39

RECONNAISSANCE SURVEYS

Reconnaissance surveys are ordinarily used as a supplement to fly grill surveys. They are made in vehicles or on foot by observing the abundance of flies in favored resting places, and recording the densities as estimated grill readings. They provide data to guide control operations in areas lacking grill coverage; to facilitate rapid control in times of epidemic or disaster; to serve as post-treatment evaluations of space spray applications; and, to serve as preventive maintenance inspections during times of low fly density. Reconnaissance surveyors should be very familiar with fly grill survey methods.

FLY EGG COUNTS

These are used in some food sanitation surveys, such as in tomato products (Buss, 1958; Gould, 1958). Other food sanitation fly survey methods are outlined in U.S. Food and Drug Administration (1960).

SURVEYS FOR NON-DOMESTIC FLIES

Surveys must be based upon a thorough knowledge of the ecology of the species involved. Some commonly employed techniques are: *biting and landing rates* of adult flies; *special bait traps* for flies attracted to certain animals, foods, or breeding material; and *larval counts* made from uniform quantities of breeding materials. In some cases breeding materials of known quantity may be put out to attract egg laying females, and emerging larvae are counted. Suitable survey techniques for non-domestic flies of public health importance are itemized in figure 5.40.

SCIENTIFIC NAME	*COMMON NAME*	*SUITABLE SURVEY TECHNIQUES*
Blepharoceridae	Net-Winged Midges	Adult biting rate; larval count from fast flowing streams.
Chloropidae	Eye Gnats	Liver bait trap for adults; larval count from organic debris.
Ephydridae	Shore Flies	Larval count from highly polluted or mineralized waters.
Heleidae	Biting Midges	Larval count from around edges of fresh or brackish water.
Hippoboscidae	Keds and Louse Flies	Ectoparasite count from combings of sheep, birds, and other hosts.
Phoridae	Humpbacked Flies	Larval count from putrid organic materials.
Piophilidae	Cheese Maggots (Cheese Skippers)	Larval count from cheese and smoked meat destined for use as food.
Psychodidae	Sand and Filter Flies	Adult biting rate; special bait trap employing attractive animal or castor oil.
Rhagionidae	Snipe Flies	Adult biting rate; common larval breeding sites as yet unknown.
Sepsidae	Sepsid Flies	Adult net surveys from over dung and other decaying organic matter.
Simuliidae	Black Flies	Adult biting rate; larval count from fast flowing streams.
Tabanidae	Deer and Horse Flies	Adult biting rate; pyrethrum emulsion larval survey (see Anthony, 1957).
Therevidae	Stiletto Flies	Larval count from earth, fungus, and decaying wood.
Tipulidae	Crane Flies	Larval count from decaying vegetable matter.
Tylidae	Tylid Flies	Larval count from feces and other decaying organic material.

Figure 5.40
Survey Techniques for Non-Domestic Flies

SAMPLE PATTERNS

Selection of areas to be sampled must be based upon a clear understanding of what information is required. In domestic fly surveys, city blocks are commonly used as the evaluative unit. In other fly surveys, a suitable area must be selected, based upon the habits of the species involved. The problem section is divided into evaluative units of approximately 10 continuous areas. In places where fly densities are normally low, the size of the evaluative unit may be expanded to include up to 20 areas. When it is impossible to complete surveillance of all areas within a single day, daily coverage should be limited to completing surveys in one or more units, and the sequence of inspection should be varied to prevent areas from being surveyed in the same sequence throughout the season. In any case, 3 types of evaluative areas are usually selected.

FIXED-STATION AREA

Within each unit, that evaluative area exhibiting the greatest fly problem, as indicated by adult density and breeding potential, is designated the fixed-station area. If this area shows densities repeatedly lower than companion areas in the same unit, the fixed station should be moved to a high density area.

RANDOM-STATION AREA

Within each unit, a second evaluative area is chosen by numbering all areas in the unit, putting the numbers into a container, and drawing out one number for inspection. A new drawing is made for each week, and all block numbers are used in each drawing.

DUMP-STATION AREA

An area which exhibits abnormally high adult populations and breeding potential, and is therefore not typical of the other areas in the section, is designated a dump-station area, and may be considered separately in evaluating the fly situation. A dump-station area should never be used as the fixed-station area for the unit.

Both pre-control and post-control surveys should be made in order to adequately evaluate control operations:

A. Pre-Control Surveys
   1. Tabulate fly breeding places and their relative importance.
   2. Measure the existing fly populations.
   3. Evaluate the problem, allowing for selection of the best control practices for each problem area.
   4. Obtain data for informing the public and local officials concerning the program.

B. Post-Control Surveys
   1. Evaluate control operations.
   2. Measure the persisting fly population.
   3. Indicate which control measures are the most effective.
   4. Publicize control results stimulating community interest and cooperation.

LARVAL SURVEYS

Larval surveys are commonly employed in mosquito control programs, but have been little used in fly control. This has been due primarily to difficulty in locating fly larvae and to the inability of most fly control personnel to identify them.

However, the value of larval surveys is tremendous. Such surveys serve to demonstrate the relative significance of available breeding media and to emphasize the importance of sanitation in fly control.

Mosquito control personnel have learned not to control all water, but rather to concentrate on water which produces a significant number of mosquitoes. Fly control personnel can learn, likewise, to concentrate on those breeding materials which produce the greatest numbers of flies. See Haines, T. W. 1953. Breeding media of common flies. American Jour. Trop. Med. Hyg., *2* (5):933-940.

USE OF SURVEY INFORMATION IN CONTROL PROGRAMS

The success of fly control is largely dependent upon the coordination of the entomological surveillance and the control program. For example, the following grill index has been used for evaluating the need for domestic fly control:

Block Grill Average	Control Recommendation
0 to 2	no treatment
2 to 5	treat when possible
5 to 20	schedule treatment
20 and more	immediate treatment

By comparing averages from survey to survey, it is possible to rate each area and group of areas. Rating systems are relative and do not compare total fly populations. As yet, the relation of survey-counts to total population is undetermined. Regardless of the type of control program or the methods used in evaluation, surveys should be conducted both before and after each control operation.

DOMESTIC FLY CONTROL BY ENVIRONMENTAL SANITATION

The control of filth-frequenting flies has been a major problem of health departments during recent years. During the horse-and-buggy era, when myriads of flies bred in stables throughout our land, the fly was tolerated as an unavoidable nuisance. When, however, flies were condemned as carriers of typhoid and half a hundred other diseases, homes were screened; and the use of the spray gun became a domestic rite. Conditions improved when the automobile replaced the horse on the street, but the industrial migration from farm to city was in full swing. Living quarters were crowded, and environmental sanitation reached a low ebb. Refuse accumulated, and the fly problem became acute. It remains so to this day. The synthetic organic insecticides gave temporary relief; but, as resistance became a problem, it became increasingly obvious that emphasis must be placed upon environmental sanitation as a primary fly control method (West, 1951; Burton, 1958; Huge, 1959; McDuffie, 1959).

Refuse, the waste of modern living, has replaced animal manure as the chief source of domestic flies. The primary phase of modern domestic fly control devolves, therefore, upon refuse control. Sewage and industrial wastes, while not usually the number one fly breeding source, can be major fly producers. Since some of these wastes are heavily laden with disease germs, they become important beyond their volume from the public health standpoint. Animal feeds and excrement, plus a large number of minor breeding sources, can add significantly to the fly population. These sources must be sought out and eliminated, and usually represent the "polishing up" phase of the fly control program (Darling, 1959).

REFUSE STORAGE

Sanitary refuse storage on each and every premise is a basic requirement for effective domestic fly control.

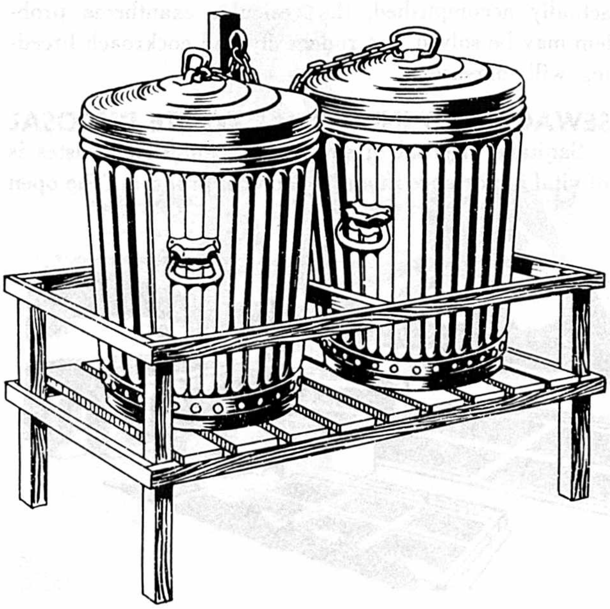


Figure 5.41 **Refuse Storage**

Ideally, all garbage should be wrapped in paper and stored in durable, rust-proof containers which are kept clean and covered. Enough containers should be present on each premise that refuse need never be stored in boxes, cartons, bags, or on the ground. Containers should be kept on a neat and easily cleaned rack, platform or slab. Spillage of garbage on soil can be a minor source of flies, and this should be avoided. Cans should be 32-gallon capacity or smaller. Larger cans make the job of collection too difficult. Ashes, wet garbage, or other heavy refuse should be stored in cans of 20-gallon capacity or less. Occupants should be familiar with local collection requirements. Most cities provide separate collections for household garbage-rubbish and for trash (leaves, metal, glass, brick, etc.). The public health worker has his greatest opportunity for community fly control through a program of better refuse storage.

REFUSE COLLECTION

Refuse must be removed from premises at regular intervals, spaced to prevent development of flies. To accomplish this, household refuse must be collected twice weekly, and business refuse daily. If flies do gain access to garbage, it will be removed and destroyed before a new generation of flies can reach the adult stage. Collection personnel should be neat, courteous, and efficient. They should take care not to spill refuse or damage cans. Collection trucks should be of the packer type, or designed for pickup of portable containers, and should have qualified operators. Trucks should be kept clean. Collection routes should be efficient and some system devised to assure that no premises are missed. The collection system should be designed for the improvement of sanitation, and not for the convenience of the collection agency (Ruskin and Blanding, 1958).

REFUSE DISPOSAL

THE OPEN DUMP

This is an ancient but unsatisfactory method of refuse disposal which is still found near many of our cities. A dump is a blight on the health of any community, and should be replaced as rapidly as possible with a more sanitary disposal system.

THE SANITARY LANDFILL

An adaptable and economical method of handling garbage. Refuse is compacted and covered with 24 inches of packed soil effectively eliminating fly, mosquito, and rodent breeding (Black and Barnes, 1958). There is no

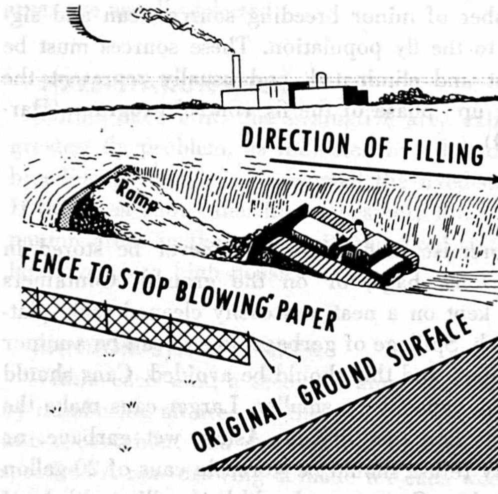


Figure 5.42 Sanitary Landfill

need for separate disposal of brush, concrete, or other rubbish as all these materials are placed in the fill. Submarginal land may be reclaimed as a by-product, further reducing populations of mosquitoes and flies, and increasing property value.

THE HOME GARBAGE GRINDER

Of merit as it eliminates storage of garbage on the premise. Some cities operate municipal garbage grinders located conveniently in the community (Erganian *et al.*, 1952).

THE INCINERATOR

A practical method of refuse disposal in large cities where sites for landfills are too remote for economical use. Complete combustion at temperatures of 1,400°F. to 2,000°F., destroys organic material that would breed flies and rats. Higher temperatures may cause operational difficulties. Poorly designed and/or operated incinerators only char garbage and do not prevent fly and rat breeding in the residue. In modern incineration,

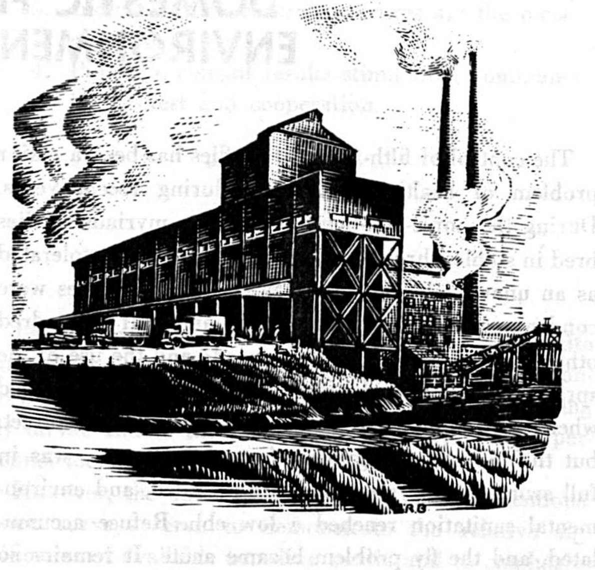


Figure 5.43 Incinerator

metal, steam, and ashes are salvaged and sold, allowing the plant to operate at a profit.

HOG FEEDING

A method of salvaging some of the food content of garbage—but usually its value is more than offset by the greatly increased public health problems of fly breeding, rodent breeding, trichinosis, etc. Most states require cooking of garbage fed to hogs. When proper cooking is actually accomplished, the vesicular exanthema problem may be solved, but rodent, fly and cockroach breeding will increase.

SEWAGE AND INDUSTRIAL WASTE DISPOSAL

Sanitary disposal of sewage and industrial wastes is of vital importance in any fly control program. The open

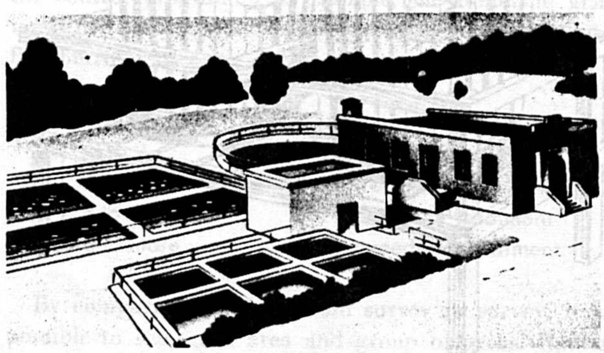


Figure 5.44 Sewage Plant

privy produces large number of flies, and each filth-laden fly is a menace to human health. The sanitary pit privy with closed pit and housed seat is a vast improvement, but even this is dangerous to health, and should be replaced as soon as possible by modern and efficient disposal facilities. The properly constructed septic tank is a temporary solution to this problem in rural and newly-developed areas, but cities and towns should provide sanitary sewers and a complete sewage treatment plant. Exposed wastes are too dangerous to human health to be tolerated.

Food canneries, feed mills, abattoirs, and packing houses produce large quantities of organic wastes that require proper storage and disposal. These wastes are often the most prolific fly breeding sources in a community. Some of the more important wastes are spilled feed, blood, urine, paunch contents, melon rinds, and pea hulls. Breeding often becomes so great under these conditions that vast hordes of flies will move out into surrounding areas seeking less crowded breeding sites (Linam and Rees, 1956-7).

Each type of industrial plant has special waste problems that must be solved if effective fly control is to be achieved. Large plants can often use wastes to produce valuable by-products, such as fertilizer or salvaged fats. Smaller plants must resort to other means, such as the sanitary landfill, for waste disposal. Storage in closed containers for a minimum time, plus adequate disposal, will go a long way toward eliminating the problem. The paving of waste-storage areas will prevent organic matter from soaking into the soil and causing objectionable

Figure 5.45 **Animal Waste Control**

odors and fly breeding. Concrete platforms with suitable drains can be maintained in a sanitary condition with a minimum of labor. Waste-storage areas should be cleaned daily.

ANIMAL FEEDS, EXCREMENT AND OTHER MINOR BREEDING SOURCES

So-called minor breeding sources may play a greater or lesser role in the domestic fly problem. In any case, a concerted effort should be made to locate and eliminate as many of these as possible. Look for such things as animal feeds, which are kept wet by rainfall, accumulations of animal manures improperly spread or poorly stored, and for dog stools, chicken manure, and other animal excrement not usually surveyed. In short, search out and eliminate any accumulation of organic material which remains moist enough to produce flies (Hoffman, 1957; Wilson and Gahan, 1957).

WEEDS

Weeds are an open invitation for large populations of flies. They provide extensive and varied cover for the pests, make insecticide application difficult, and prevent

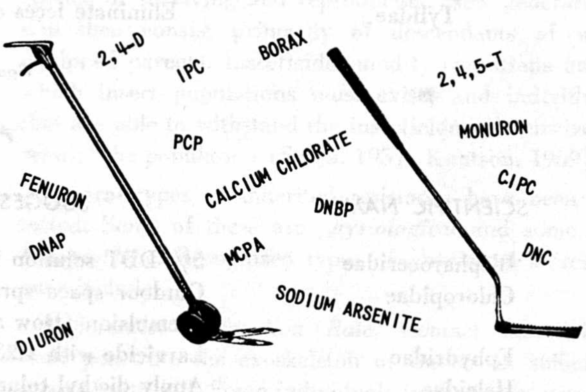


Figure 5.46 **Weed Control**

adequate control of refuse, feces, and other breeding media. Use weed killers (2, 4-D; 2, 4, 5-T; and others) when safe and practical. Use mowers, clippers, and kerosene weed burners when weed killers might endanger valuable plant life (Kernaghan and Davies, 1959). Local health departments should require reasonable weed control on vacant property.

ENVIRONMENTAL CONTROL OF NON-DOMESTIC FLIES

Elimination of larval habitats and adult resting places can bring about control of many non-domestic flies of public health importance. The general recommendations that can be made are shown in figure 5.48.

SCIENTIFIC NAME	*METHODS OF ENVIRONMENTAL CONTROL*
Blepharoceridae	Modify flow of streams where larvae live.
Chloropidae	Eliminate accumulations of damp plant debris (Mulla, 1958).
Ephydridae	Eliminate standing polluted or mineralized water.
Heleidae	Eliminate fresh or brackish standing water.
Hippoboscidae	Keep healthy animals away from those that are infested.
Phoridae	Eliminate deposits of putrid organic material.
Piophilidae	Keep infested and non-infested foods separated.
Psychodidae	Eliminate rock piles and debris.
Rhagionidae	None developed as yet.
Sepsidae	Eliminate dung and other decaying organic matter.
Simuliidae	Modify flow of streams where larvae live (McMahon, *et al.*, 1958).
Tabanidae	Elimination of fresh standing water may help.
Therevidae	Eliminate deposits of decaying fungus and wood.
Tipulidae	Eliminate deposits of decaying vegetable matter.
Tylidae	Eliminate feces and other decaying organic matter.

Figure 5.47

SCIENTIFIC NAME	*SUGGESTED METHODS OF CHEMICAL CONTROL*
Blepharoceridae	5% DDT solution in drip cans at 0.1 lb. DDT per acre of water surface.*
Chloropidae	Outdoor space spray with 1% lindane, or 2.5% malathion solution or emulsion (Dow and Willis, 1959; Mulla, 1960).
Ephydridae	Larvicide with 1.25% DDT solution at 0.1 lb./acre.*
Heleidae	Apply diethyl toluamide repellent to individuals affected.
Hippoboscidae	Dip infested animals in 5% rotenone or 0.025% lindane suspension; dust sheep with 1.5% dieldrin (Pfadt and DeFoliart, 1957; Knowlton and Thomas, 1959).
Phoridae	Outdoor space spray with 5% DDT solution or emulsion.*
Piophilidae	Space spray with 0.1% synergized pyrethrins solution.
Psychodidae	Residual spray all living quarter with 5% DDT emulsion (Deruiter, 1960).
Rhagionidae	Outdoor space spray with 5% DDT solution or emulsion.
Sepsidae	Outdoor space spray with 5% DDT solution or emulsion.*
Simuliidae	5% DDT solution in drip cans at 0.1 ppm DDT for 3 to 60 minutes every two weeks during breeding season (Lea and Dalmat, 1955; Bennett, 1960).
Tabanidae	Larvicide with 2.5% dieldrin granules at 0.3 lb./acre (Jamnback, 1957; Hoffman, 1960).
Therevidae	Outdoor space spray with 5% DDT solution or emulsion.*
Tipulidae	Outdoor space spray with 5% DDT solution or emulsion.*
Tylidae	Outdoor space spray with 5% DDT solution or emulsion.*

*Chemical treatment seldom necessary; emphasize environmental control.

Figure 5.48

DOMESTIC FLY CONTROL WITH CHEMICALS

Long before man developed a system of writing he was dreaming of a "magic potion" which would rid him of his insect pests. This dream was partially fulfilled by many civilizations when they developed insecticides of

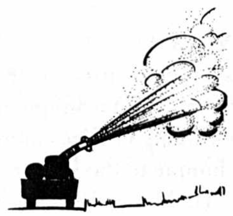


Figure 5.49 **Mist Generator**

greater or lesser effectiveness (Fay and Kilpatrick, 1958). Four great ideas have marked the search for the "magic potion":

THE FIRST IDEA

Poisonous Minerals. By mixing poisonous minerals such as compounds of arsenic, lead, thallium, boron, and copper with attractive food or breeding material, man was able to kill many insects, including flies. However, such poison baits usually attracted more flies than would ordinarily have come, and the poisonous minerals produced very little in the way of fly control.

THE SECOND IDEA

Poisonous Plants. Early man noted that some plants were safe to eat, while others would kill when eaten. Some of these poisonous plants were found to be good insecticides, and were used by many people in different parts of the world. Most of these had very little value for fly control, but one, pyrethrum, is still widely used as a space spray for flies. Indeed, pyrethrum is a keystone chemical, for no resistance to it has been verified, although it has been used for over a hundred years in large quantities.

THE THIRD IDEA

Poisonous Gases. Fumigation with poison gases, such as cyanide and methyl bromide, was once the primary method of insect control. It is still widely used for the control of stored-product pests, but it has little value in fly control, because flies are essentially outdoor creatures and, therefore, not vulnerable to fumigation.

THE FOURTH IDEA

Synthetic Organic Insecticides. The best insecticides for fly control have been synthetic organic compounds, such as DDT, methoxychlor, lindane, malathion, diazinon, and dipterex. When first employed, they give dramatic reduction in fly populations, but *resistance* to the insecticide develops rapidly, and after a number of years control cannot be maintained.

RESISTANCE TO INSECTICIDES

Resistance is the ability of insect populations to withstand a poison which was generally lethal to earlier populations. Several causes of resistance have been detected, but they are all due to the fact that *living populations are not uniform.* No two flies are exactly alike; and, within the range of differences in a large population, there are individuals able to withstand almost any onslaught. Thus, when an insecticide is put to use, most of the flies are killed; but some have the ability to withstand it (Keiding, 1959). Two basic types of resistance may be noted: (Scott, 1961c).

INHERITED RESISTANCE

Inherited resistance is a reflection of overpopulation acted upon by natural selection to produce survival of the fittest. More individuals are born than can survive; populations are highly variable and the individuals that are best equipped for prevalent conditions stand the best chance of surviving and reproducing. New generations will then consist primarily of descendants of well-equipped parents. Insecticides modify conditions under which insect populations must exist; and individuals that are able to withstand the insecticide will survive to rebuild the population (Sacea, 1957; Knutson, 1959).

Several types of inherited resistance have been detected. Some of these are *physiological* and some are *behavioristic.* Recognized types of physiological resistance include:

Differential Absorption Rate. Contact insecticides must penetrate the exoskeleton of insects in sufficient quantities to kill. Some individuals in the insect population have slower absorption rates than others. During routine chemical applications, individuals with slow absorption rates receive sublethal doses.

Storage. Some individuals in the insect population are able to store the insecticide in a physiologically nonsensitive tissue such as the fat body before it can kill.

Excretion. Some members of an insect population are able to excrete the insecticide before it can kill.

Detoxication. Certain individuals in an insect population are able to detoxify the insecticide before it can kill. This detoxication is usually brought about by enzymatic action. Detoxication products may be stored, excreted, or metabolized.

Alternate Accomplishment of Blocked Functions. Insecticides kill by interfering with the biochemical balance of the insect. Some individuals can regain normal activity by substituting another biochemical system for the one damaged by the chemical.

Recently, cases of resistance which are *behavioristic* rather than physiological have been noted. Recognized types include:

Habitat. A few members of an insect population occupy a habitat different from that of the vast majority. During routine chemical applications, the normal-habitat majority is killed while the "out-of-the-way" minority survives.

Avoidance. Some individuals in an insect population are sensitive to the insecticide, and tend to avoid it. During routine chemical applications, particularly of a residual nature, sensitive individuals survive.

TOLERANCE

Tolerance results when members of an insect population receive sublethal doses of an insecticide, and some physiological reaction occurs which protects these insects from later applications of the chemical. This protection is not passed on to the next generation. Minute quantities of highly stable insecticides, as DDT, may remain in the environment for many years, thereby perpetuating acquired resistance.

Not all reports of resistance are valid. Other possibilities should be explored. For example, did the spray crew actually apply the chemical as instructed? Was the proper chemical used in the proper manner and at the proper concentration? Was the batch of chemicals faulty? Did a new population move into the area? Did the old population rebuild itself so rapidly that reduction was not apparent? (Abedi and Khan, 1958).

SPACE SPRAYING

Space spraying involves putting a very fine mist or aerosol into areas where flies are abundant, for the purpose of killing a large number of the adults. Space sprays have no long-term action, and are not generally deadly to immature stages of flies. They are useful because they can bring about a dramatic reduction in number of adult flies, but they give only temporary relief because the population can rebuild itself in a matter of hours or days. Three techniques are commonly employed in the application of space sprays:

MIST GENERATORS

These devices issue a very fine droplet spray and distribute it with air drafts, or some other medium. The most familiar of the mist generators is the common household insecticide "bomb"; but large mist blowers are available and widely used in fly control operations.

FOG GENERATORS

These machines issue an aerosol or smoke, the particles of which are of colloidal size. Fogs are very sensitive to wind and to ground thermals and must, therefore, be used only early in the morning or late in the evening. Most fogs are heat generated, and the heat may destroy much of the insecticide. In general, they are more dramatic but less effective than mist generators.

Figure 5.50 Fog Generator

AERIAL SPRAYING

This method is used to disperse the insecticide over large areas. In general, this technique has been relatively ineffective, but continuing changes in available chemicals may bring this technique to the fore at any time (Husain, *et al.*, 1957; U.S. Air Force, 1951).

RESIDUAL SPRAYING

Residual spraying involves application of semi-permanent deposits of insecticide on a common resting place of the problem insect. These residual deposits give the best chemical control yet achieved, and may bring about dramatic fly abatement. However, residual applications accelerate development of resistance, and this greatly limits their use. The compressed air hand sprayer is the item of equipment most often used in residual spray programs. However, power sprayers, hand and power dusters, paint brushes, and other items are used in some cases. For maximum effectiveness, residual spraying must be comprehensive and well-timed. In general, fly control cannot be maintained with this technique, although temporary relief can be obtained (Gahan, *et al.*, 1957; Kilpatrick and Schoof, 1957; Lewis and Hughes, 1957).

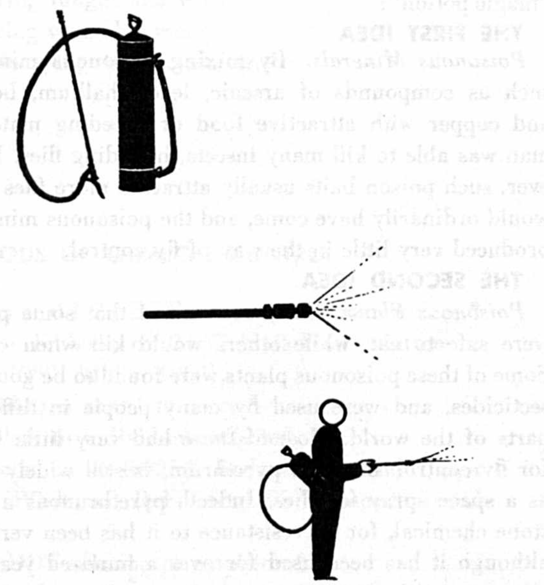


Figure 5.51 Residual Spraying

CHOICE OF CHEMICALS FOR DOMESTIC FLY CONTROL

Choice of chemicals must be guided by the presence or absence of resistance to the various insecticides (USPHS, 1961) (Ikeshoji, 1960). The following general recommendations can be made (see also figure 5.53):

RESIDUAL SPRAYS

Five percent DDT emulsion or suspension, 1% lindane emulsion or suspension, 2 to 5% malathion (with 6 to 12% sugar) emulsion or 1% diazinon emulsion.

SPACE SPRAYS

Indoors with 0.1% pyrethrins (synergized) emulsion or solution (Gharpure and Perti, 1957; Ware, 1960). Outdoors with 5% DDT, 2% lindane or 5% malathion emulsion or solution.

FLY CORDS

Ten percent parathion or 25% diazinon insecticide impregnated cord.

LARVICIDAL TREATMENT

Two and one-halt percent diazinon emulsion, 1% malathion emulsion, 2.5% ronnel emulsion, or 2% DDVP emulsion.

FLY CORDS

Fly cords are an extension of the residual spraying technique. Schoof and Kilpatrick (1957) reported good control with cotton cords (3/32-inch in diameter) impregnated with 7.5% to 10% parathion, or 25% diazinon solution hung in a building at the rate of 30 linear feet of cord per 100 square feet of floor area. Cords are suspended vertically from the ceiling high enough that persons using the building will not hit them with their heads. Flies rest on the cords, particularly at night, and are killed. Parathion cords usually provide excellent control for ten weeks, while diazinon cords give control for about seven weeks. Parathion is highly toxic to man and only experienced personnel should work with this chemical. If less experienced personnel are used, diazinon cord is preferable, but this too must be handled with care. Rubber or cotton gloves must be worn when installing fly cords, and great care must be taken to insure that a minimum of skin contact occurs. If the cord should contact the skin, the area must be washed with soap and water immediately. Control personnel must not attempt to manufacture their own cord.

Control of houseflies in a military dining hall and kitchen with parathion-impregnated cords.

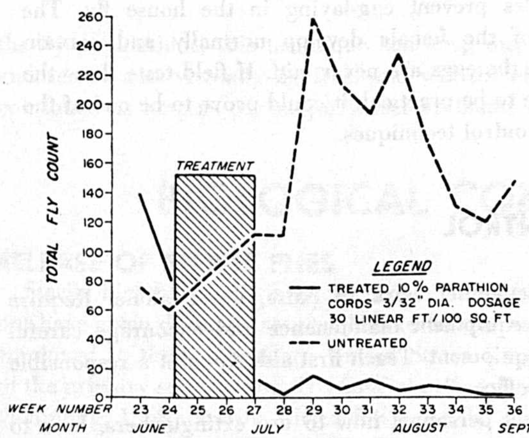


Figure 5.52

Type Application	Toxicant	Formulation	Remarks
		(For 50 gallons of finished spray)	
RESIDUAL	Diazinon	2 gal. 25% EC or 16# 25% WP plus water	Add sugar (25#) to formulation for maximum residual effectiveness. Spray surfaces at a rate of 2 or more gallons per 1000 square feet. Maximum strength permitted for Diazinon and ronnel 1.0%, malathion, 5.0%.
	Malathion	2-4.5 gal. 55% EC or 32-64# 25% WP plus water	Diazinon and ronnel are accepted for use in dairy barns including milk rooms, meat packing, and other food processing plants. Malathion is restricted to use in the dairy barn only. None are accepted for complete interior treatment of houses.
	Ronnel (Korlan)	2 gal. 25% EC or 16# 25% WP plus water	AVOID CONTAMINATION OF HUMAN AND ANIMAL FOOD, WATERING TROUGHS.
BAITS (Dry/Wet)	Diazinon	1# 25% WP plus 24# sugar; 2 fl. oz. 25% EC plus 3# sugar in 3 gal. of water.	Apply 3-4 oz. (dry) or 1-3 gallons (wet) per 1000 square feet in areas of high fly concentration. Repeat 1 to 6 times per week as required. Avoid application of bait to dirt or litter.
	Malathion	2# 25% WP plus 23# sugar	The use of permanent bait stations will prolong the efficacy of each treatment.
	Ronnel (Korlan)	2 pts. 25% EC plus 3# sugar in 3 gal. water.	
	DDVP	3-6 fl. oz. 10% EC plus 3# sugar in 3 gal. water.	All toxicants are available as commercial baits which are labeled for use in dairies and, except for DDVP, in food processing plants. None of these baits should be employed inside homes.
	Bayer L 13/59	1# 50% SP plus 4# sugar in 4 gal. water.	DO NOT CONTAMINATE FEED OR WATERING TROUGHS.
IMPREGNATED CORDS	Parathion and Diazinon	To be prepared by experienced formulators only.	Install at rate of 30 linear feet of cord per 100 square feet of floor area. Accepted for use in dairies and food processing plants. Handle and install cords per manufacturer's instructions.
LARVICIDES	Diazinon	1 fl. oz. 25% EC to 1 gal. of water	Apply 7-14 gallons per 1000 square feet as a coarse spray. Repeat as necessary, usually every 10 days or less. For chicken droppings use only where birds are caged.
	Malathion	5 fl. oz. 55% EC to 3 gal. of water	
	Ronnel (Korlan)	1 pt. 25% EC to 3 gal. of water	AVOID CONTAMINATION OF FEED OR WATER OR THE SPRAY ON ANIMALS.
	DDVP	2 fl. oz. of 10% EC to 1 gal. of water	

EC - Emulsifiable Concentrate WP - Wettable Powder SP - Soluble Powder

Figure 5.53 **Organophosphorus Insecticides Used in Fly Control**

FLY BAITS

Fly baits are also an extension of the residual spraying technique, but rapid development of resistance has greatly impaired their usefulness. A typical fly bait consists of some inert materials like ground oyster shell coated with an attractant such as sugar and an organophosphorous insecticide, often 2% malathion or diazinon. Fly baits are scattered about or set out in bait stations at the rate of 2 to 4 ounces per 1000 square feet where adult flies are abundant. The flies are attracted to the bait and are poisoned by contact with it, or when they ingest some of the poison.

LARVICIDING

Larviciding for the control of domestic flies has never proved very practicable, but new developments in this field are expected. Most common insecticides are poor fly larvicides, and treatment of larval habitats with these materials is essentially adult control designed to kill ovipositing females and newly emerged adults. Some workers have attempted to alter the chemical makeup of breeding media so that, although females lay eggs in it, the young do not reach maturity. The traditional example is the addition of borax to manure to retard fly breeding. Such treatment makes the manure unsuitable for fertilizer. Chloride of lime, used to deodorize privies, is a poor larvicide. Some chemicals which have shown promise as fly larvicides are ronnel (=Korlan) (Knapp and Roan, 1957) diazinon, hexachloroethane, orthodichlorobenzene, sodium arsenite (very toxic to man) and kerosene (inflammable). Special formulations are available from veterinarians and physicians for controlling fly larvae infesting the flesh of living animals. In general, effort should be directed toward elimination of breeding media rather than toward chemical treatment of larval habitats (Tahori, 1960; Wilson and Labrecque, 1960).

SELF-APPLICATING DEVICES

These devices for treating livestock with insecticides to control flies are widely used (Hargett and Turner, 1958; Rowell, 1959).

SYSTEMIC TREATMENT OF ANIMALS

Systemic treatment for the control of fly larvae infesting flesh is developing rapidly, but is not as yet suitable for routine public health work (Bushland, 1958; Drummond and Moore, 1959; Drummond, 1959). Similar treatments to make feces poisonous to flies are being developed (Quisenberry, *et al.*, 1958; Goodman, 1958; Sherman and Ross, 1960).

FLY REPELLENTS

Repellents are coming into more and more use to (1) keep flies away from animals, and (2) keep flies away from doors of food-service establishments. Livestock smears and sprays commonly contain cloves, safrol, pine oil, camphor, or tabutrex (Bruce and Ayars, 1958). Diethyl toluamide is an excellent fly repellent for human use; and will repel mosquitoes, ticks, and mites as well. Several proprietary materials are available for use as fly repellents around food-service establishments (Goodhue and Howell, 1960; Bovingdon, 1958; Ikeda, 1958 and 1959; Grannett, 1960).

FLY ATTRACTANTS

Attractants have been used to a limited extent to attract flies to specially treated breeding media. This, however, has been found to have little use in most large control programs (Snow, 1957; Acree, *et al.*, 1959). Fly paper once widely used for fly control, has fallen into general disuse as it only serves to attract more flies than would ordinarily be present.

ANTI-OVIPOSITIONAL CHEMICALS

Workers at the Medical Research Laboratories, Israeli Defense Forces, report that two fluoridated hydrocarbon insecticides prevent egg-laying in the house fly. The ovaries of the female develop normally and contain eggs, but the eggs are never laid. If field tests show the technique to be practical, it could prove to be one of the best fly control techniques.

SAFETY IN FLY CONTROL

Safety is an important part of any public health activity. However, because of repeated contacts with poisons, machinery, and flammable materials, fly control personnel must develop special concepts of safety if they wish to avoid injury (Scott, 1961d).

In approximate order of importance, safety hazards for fly control personnel include highway accidents, falls, fires and explosions, poisoning, and injury associated with mechanical equipment or improper lifting.

Train and supervise unskilled workers. Keep innocent bystanders away. Safeguard supplies and equipment. Have personnel work in pairs, never alone. Require regular equipment maintenance and encourage careful use of equipment. Teach first aid. Appoint a responsible "safety officer."

Instruct personnel how to use extinguishers, how to call fire department, never to carry "strike-anywhere" matches, never to smoke around pesticides, to leave a chemical fire immediately, and how to avoid pesticide poisoning.

Demand safe equipment operation. Provide necessary safety apparatus. Store machines securely.

MECHANICAL AND PHYSICAL CONTROL OF DOMESTIC FLIES

SCREENING

Screening buildings is the most widely used fly control technique. Although costly, and non-detrimental to the fly populations, this technique can keep our homes and restaurants virtually fly free, and will therefore be continued as long as our major insect problems remain unsolved. Screens are usually made of copper, aluminum, plastic, or some other noncorrodible material. They should be mounted on durable frames, and should not detract from the beauty of the building. Size of screen should be about 16-mesh in order to give the greatest effectiveness without undue loss of light. Screens should fit tightly in the window or door frame so that flies and other insects cannot enter around the edges (Porter, 1959).

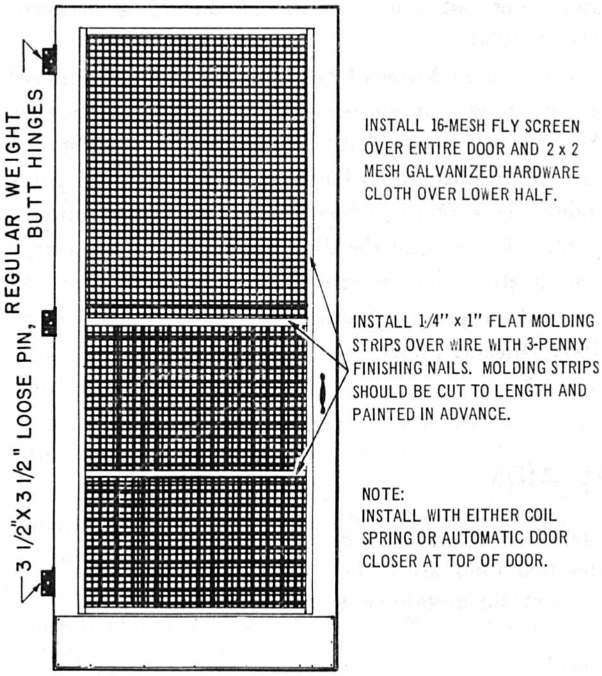


Figure 5.54 Fly-Proof Screen Door

FLY TRAPS

Traps, while useful for survey purposes, merely harvest the excess fly populations and give little immediate relief, and no long-range control.

ELECTROCUTION

Electrocution has proven effective under certain conditions. Two common techniques are used. In the first, a fly trap is electrified. In the second, electrification of window and door screens is accomplished using house current transformed to low amperage and high voltage (3,500 to 4,000 volts is desirable). When flies light on the screens they are immediately killed, yet the screens will not harm a human being or other large animal. Installation of electric screen is very expensive, but has been used where the fly problem is acute.

ELECTRIC FANS

Fans mounted over doorways leading to food-serving establishments will keep out most flies. Large buildings may have "air doors" which keep out dust, smoke, and insects, but which are hardly noticeable to persons passing in and out.

BIOLOGICAL CONTROL OF DOMESTIC FLIES

RELEASE OF STERILE FLIES

Sterile flies have only been used to a limited extent, but have given dramatic results. This technique has been employed in the southeastern United States for control of the primary screw-worm fly (*Callitroga hominivorax*) (Knipling, 1960) and in Africa for tsetse fly (*Glossina spp.*) control. Laboratory reared flies are sterilized by exposing the pupae to gamma rays from radioactive cobalt. Large numbers of sterilized flies are released each week. Sterile males compete with wild males for mates, and since each female mates only once, large numbers of sterile eggs are produced. Release of sterile flies is continued until the population falls to an extremely low level.

DISSEMINATION OF PATHOGENIC ORGANISMS

Pathogens for insect control have long appealed to man. However, great caution is needed in the employment of such techniques, since many diseases inimical to flies are also dangerous to man, or to other animals. In general, dissemination of pathogenic organisms is not a suitable technique at the present time for community fly control programs. If a suitable disease were discovered for use in this way, fly resistance could be expected to develop rapidly and greatly limit its use. *Bacillus thuringiensis,* is being used experimentally for fly control (Hall and Arakawa, 1959; Dunn, 1960).

INTRODUCTION OF PREDATORY ANIMALS

Predator introduction for domestic fly control has never been attempted on a large scale. On farms, a great deal of fly control is accomplished by domestic fowl. Many fly predators are undesirable occupants of the city, and their introduction would be unwise. In addition, most predators only harvest the excess flies without bringing noticeable reduction in fly populations.

ORGANIZED FLY CONTROL

Efficient fly control benefits the entire community. It can best be accomplished with an organized program, using all effective means. Since most fly control requires the cooperation of the entire community, education is the number one requirement of a good program. It begins with a realization of the problem by responsible individuals, extends through the orientation of public officials, and reaches its fruition in the education of all people in the community. Fly surveys, to determine the extent of the problem and to guide the control operations, must be made. Then, efficient and effective control measures must be taken. Re-survey can evaluate the results of the effort and point out where additional control is necessary (West, 1958).

Once a high degree of fly abatement has been achieved, a continuing program is necessary to maintain the gain. Yet, it is in this area that fly control programs most often fail. When flies are no longer a serious problem, public interest lags, other problems take away the attention of public officials, and the flies begin a subtle but certain reoccupation. Incorporate continuing control into the original program (Anonymous, 1958; Martin, *et al.*, 1957; Ricker, 1958).

AUDIOVISUAL AIDS

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BIOLOGY OF DOMESTIC FLIES (M-80), motion picture, black and white, sound, 9 minutes, 1951.

BIOLOGY OF DOMESTIC FLIES (F-80), filmstrip, color, sound, 9 minutes, 1951.

COLLECTION OF ADULT FLIES (5-122), filmstrip, color, silent, 1949.

COLLECTION OF ADULT FLIES (4-085), motion picture, color, sound, 6 minutes, 1949.

THE COLLECTION AND SHIPMENT OF INSECTS (F-256), filmstrip, color, sound, 17 minutes, 1957.

COMMUNITY FLY CONTROL OPERATIONS (4-094), motion picture, black and white, sound, 12 minutes, 1952.

FLY CONTROL THROUGH BASIC SANITATION (4-090), motion picture, color, sound, 9 minutes, 1950.

FLY DENSITY SURVEY BY THE GRILL METHOD (4-086), motion picture, color, sound, 6 minutes, 1949.

FLY DENSITY SURVEY BY THE GRILL METHOD (5-133), filmstrip, color, silent, 28 frames, 1949.

HEATH HAZARDS OF PESTICIDES (M-204), motion picture, color, sound, 14 minutes, 1958.

INCINERATION (M-353), filmograph, color, sound, 13 minutes, 1960.

REFUSE DISPOSAL BY SANITARY LANDFILL (M-228), motion picture, color, sound, 13 minutes, 1956.

RESIDUAL SPRAYING (4-091), motion picture, color, sound, 9 minutes, 1950.

THE SANITARY LANDFILL, PART I — Operating Procedures (F-229a), filmstrip, color, sound, 7 minutes, 59 frames, 1957.

THE SANITARY LANDFILL, PART II — Small Community Landfills (F-229b), filmstrip, color, sound, 6 minutes, 41 frames, 1956.

SANITARY STORAGE AND COLLECTION OF REFUSE (M-4), motion picture, color, sound, 19 minutes, 1952.

SPACE SPRAYING OF INSECTICIDES (M-442), motion picture, color, 11 minutes, 1961.

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