# LABORATORY OBSERVATIONS ON THE LIFE HISTORY AND HABITS OF THE FACE FLY, Musca autumnalis DeGeer (DIPTERA: MUSCIDAE)

by

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# TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF PLATES

# INTRODUCTION

Since the discovery of the face fly (Musca autumnalis DeGeer) in Nova Scotia, Canada, in 1952 (Vockeroth 1953), it has become a serious pest of livestock, especially dairy and beef cattle and horses. The fly annoys livestock by feeding on the moisture around the eyes, nose, and mouth during warmer months. This interferes with normal grazing, causing a decrease in beef and milk production. Thus, it has caused great concern to veterinarians and entomologists. Although this fly has not been proved to be a vector of any disease, there is evidence to suggest that it might be involved in transmission of leprosy, pinkeye, conjunctivitis, infectious abortion of cattle, and mammalian eye worm, Thelazia spp (Herms & James 1961). Minor annoyance to swine, sheep, dogs, man and wild animals does occur.

Several investigators have conducted field and laboratory studies on the biology of this insect (Hammer 1942, Tesky 1960). Chemical control studies have also been done by Bruce et al. (1960), Treece (1960), Anthony et al. (1961), and others. However, complete knowledge of this insect's biology and behavior is still unavailable.

In the light of the extreme importance of the face fly at the present time, a complete knowledge of the life history and habits would

seem to be essential to research workers if efforts to combat this insect are to be successful. Therefore, the objectives of this study were as follows:

1. To ascertain and describe each life stage of this insect.
2. To observe the habits of this fly and the effect of certain environmental factors capable of influencing its life pattern.
3. To improve the mass rearing techniques used in propagating this species under artificial conditions by introduction of easy, practical procedures.

# REVIEW OF LITERATURE

West (1951) reported that synonyms of Musca autumnalis DeGeer include: M. continua R. D.; M. corvina Port.; M. floralis R. D.; M. grisella R. D.; M. ludifacies R. D.; M. nigripes Panz.; M. ovipora Port.; M. prashadii Patton; M. rustica R. D.; and M. tau Schrank. He also indicated that M. autumnalis autumnalis DeG. is considered to be the typical subspecies found in Europe, Palestine, Kashmir and Shantung. The other three subspecies are found in Africa. Tesky (1960) considered the fly which causes concern in North America to be subspecies M. autumnalis autumnalis DeG.. According to Sabrosky (1959, 1961), the face fly was found in Virginia in 1958, and he believed that the fly was an immigrant species and perhaps a relatively recent arrival.

This fly received little attention until 1957. It was then abundant enough on cattle to cause the animal noticeable discomfort (Fales et. al., 1961). Intensive investigations on face fly control were carried out by Bruce et al. (1960), Treece (1960), Anthony et al. (1961) and others.

The veterinary importance, behavior and biology of the face fly were first intensively studied by Hammer (1942) in Denmark. According to his report, the fly is a facultative blood sucker, but it also feeds on nectar, dung liquid, and secretion from animals. Nectar is the principal diet of flies from the time they come out of hibernation until the cattle are let out in the field. Blood and serum exuding from

wounds made by biting flies attract the face fly. However, Tesky (1960) considered that face flies feed primarily on tears, saliva, and nasal mucous.

In Europe, the flies are found in the field from the end of April and beginning of May until October (Graham-Smith, 1916; Hammer, 1942). In Ontario the fly population increased rapidly during July to a maximum of about 45 flies per animal face, then its activity decreased and ceased about the end of October (Tesky, 1960). Hammer (1942) found the flies feeding on cattle only during the daylight hours and most abundantly on cattle near woods, game coverts, swampy areas, and many hedgerows. Male flies were seldom noted on cattle.

Large numbers of adult M. autumnalis have been reported hibernating in houses (Graham-Smith, 1918; Reh, 1927; and Hammer, 1942). Although adult flies were not observed hibernating in the field, it seemed likely that they hibernated in cracks and crevices in the bark of trees and elsewhere (Hammer, 1942).

Most female face flies probably mate only once in their lifetime according to Tesky (1960). Conspicuous objects in the field, such as a lonely bush, a rock, a cow or a cart, are believed to be the sites of mating. Males resting on such objects darted out and attached themselves to females that were flying past. The pairs dropped to the ground to complete mating (Hammer, 1942). Treece (1960) stated

that Hammer's observation of a "mating flight" is to some extent correct in that occasionally the mating flies fall to the floor of the cage. Most mating took place on the sides, some on the ceiling of the cage, but none was observed on the cage floor.

Field observations of the face fly were first recorded by Rouband in 1911 (West, 1951). He mentioned that the fly bred chiefly in cow dung in tropical Africa. Crumb et al. (1917) working with the housefly, concluded that an oviposition stimulant to the female flies was $CO_2$. Cow dung lost its attractiveness for ovipositing flies within an hour of deposition (Tesky 1960). This was believed due to the rapid formation of a crust over the surface of the dropping.

Derbeneva-Ukhova (1942) considered that M. autumnalis DeG. belongs to the ecological group of flies in which the eggs are laid at different times, though all are matured together in the ovary. Glaser (1923) working with M. domestica found that unfertilized females laid fewer eggs than fertile ones, and concluded that the male provided an important stimulus. According to Hammer's observation (1942), female face flies crept over the surface of the dung and eggs were laid singly, being pushed so far into the dung that only the respiratory apparatus was on the surface of the dung. Frequently, batches of five to eight eggs were laid close together. Flies were not observed to lay their full complements of eggs in one patch of dung (Tesky, 1960),

and oviposition began 44 hours after mating (Treece, 1960).

Hammer (1942) found 17 to 31 eggs ( av. = 24.6) per female in the ovaries, but the most common number of eggs was 24-25. The eggs had the addition of a stalk or mast on the upper end as described by Hammer (1942). He also determined that the mast was a respiratory structure and must be exposed for egg survival.

In Denmark, Hammer (1942) observed average incubation periods of 10 1/2 and 23 hours for eggs laid in dung before 10 a.m. and after 10 a.m., respectively. At an air temperature of 23°C degrees, the incubation period required 13 hours. Tesky found that at an air temperature not exceeding 26.6°C, the incubation period was less than 21 hours. Obviously, the incubation period depends upon the temperature; the high and low temperature prolonging the incubation periods of some muscoid fly eggs (Melvin, 1934).

The young larvae emerge directly into the dung and commence tunnelling through it (Tesky, 1960). Three to four days were required for larvae to complete their development in manure in the field (Tesky, 1960; Treece, 1960).

Hammer (1942) found 64 species of flies associated with cattle droppings in Denmark, and these insects, by predation and modification of the physical structure of the environment adversely affected the survival of M. autumnalis. According to Tesky's observation, larval

mortality in dung is very high, ranging from 50 to over 90 per cent. Predation and rainfall are two important factors.

The full-grown larvae may migrate up to four feet from the droppings burrowing into the soil to pupate about 1/4 inch below the surface (Tesky, 1960). Hutchison (1914) working on the housefly concluded that the migratory habit appears in the late stadia of third instar larvae in response to various internal and external stimuli; moisture is perhaps the most important factor in determining the direction of their travel and choice of a place for pupation.

The duration of the pupal period was seven days in pupae reared in the laboratory at 24°C, and ten days in the field (Tesky, 1960). Development from egg to adult required approximately three weeks in Denmark (Hammer, 1942), about two weeks in Ontario (Tesky, 1960), and eight to twelve days in Ohio (Treece, 1960).

Characteristics of muscoid larvae have been studied by many authors. The most prominent characters adapted for classification and identification as described by Knipling (1936) are (1) the size and structure of cephalopharyngeal sclerites; (2) size and general appearance of the larvae; (3) shape, size, and distribution of spines, and (4) size and shape of posterior spiracles. Other less important diagnostic characters are: size and number of papillae on the border; general appearance of anal area, and structure of the pseudocephalic segment.

In 1911, Howard described the larvae of M. domestica and said that the posterior spiracles have one slit in the first stage, two slits in the second stage, and three slits in the third stage. Tesky (1960) stated that the larvae of M. autumnalis pass through three stages. The face fly pupae are similar in size and shape to the house fly pupae (Tesky, 1960), but with whitish color (West, 1951).

The characters of the adult face fly were described by Austen (1926), Patton (1933), and van Emden (1939). Vockeroth (1953) stated that specimens of M. autumnalis appeared distinctly larger and heavier than those of M. domestica. He also presented a key for separating the two species.

On the relationship between duration of development and temperature, Peairs (1927) stated that the rate of development of certain insects is directly affected by the temperature. He also stated that, within an insectary, temperatures which undergo daily variations similar to outdoor temperature fluctuation have a more favorable effect on the rate of insect development than does a constant temperature. Feldman-Muhsam (1944) in his study of M. domestica vicina indicated that the influence of temperature is greater than that of humidity on the longevity of the flies. Dakshinamurty (1948), working with the house fly, noted that low relative humidity was favorable to fly activity at high temperatures; however, at lower temperatures differences in relative humidity did not coincide

with any marked differences in activity. As noted by Beattie (1928), the thermal death points, which are the points beyond the normal temperature range, for blow-fly survival were definitely influenced by humidity. He concluded that saturated and dry air had the effect of lowering the thermal death point; relative humidity from 60% to 80% were favorable for survival, and 70% was found to be an optimum point.

Glaser (1923) considered that carbohydrates are an important factor in the longevity of adult house flies. Also carbohydrates together with proteins or blood serum are necessary oviposition factors. According to Tesky (1960), only the face flies feeding on blood produced gravid females. Cow dung was not important. However, Fales et al. (1961) stated that fresh manure is needed as an adult food as well as an oviposition medium. Derveneva-Ukhova (1942) considered that the face fly is able to obtain its nitrogenous materials for egg maturation from dung as well as from blood.

In general, muscoid flies are most active in bright sunshine (Graham-Smith, 1916). The response to illumination in face flies was observed by Fales et al. (1961). They stated that laboratory-reared face flies become very active and the females readily oviposited after an hour or more exposure to actual or artificial sunlight. They further stated that specimens not exposed to sunlight either failed to oviposit or became sluggish.

# MATERIALS AND METHODS

This work is based exclusively on laboratory observations made from June to September, 1962 in the V. P. I. insectary. A stock colony was maintained in 12 x 12 x 12 inch screened cages. A mixture of powdered skim milk and granulated sugar at the ratio of 2:1 was provided for the adult flies at all times. A cup of clean water and about 10 ml of citrated bovine blood were served daily. Eggs were deposited in fresh cow dung packed in 10 oz. cardboard containers which were introduced into the cage every day. The next day these cartons were then transferred to a flat pan containing sand. A given number of flies were separated from the stock colony. They were confined in 8 x 8 x 8 inch special screened cages.

By means of small forceps, eggs were pulled out of the surface of cow dung, then transferred into water. Larvae of different ages were picked up from rearing manure and dipped into water. Both washed eggs and larvae were then preserved in AGA solution for further observation and dissection. A binocular microscope and Fisher magnifier (Model M-208) were employed to study the morphology of each stage and to detect the duration of the egg and larval stage.

A cabinet which maintains conditions of constant temperature and relative humidity was used. The cabinet constructed with wood and clear polyethylene plastic was 15 1/2 feet long, 4 1/2 feed wide, and

2 1/2 feet high with three doors on each side. Heat was provided by a "thermo-dial" heater (1350 watt), with a built-in thermostatic control and fan circulator. Humidity and additional air circulation was obtained by means of small fans mounted at each end of the cabinet and blowing over trays of water (Turner and Morgan, 1960). Two sun lamps (275 watt) were placed on each end as a light source to stimulate oviposition in the adult fly. hygrothermograph records and maximum-minimum temperature readings were maintained in the cabinet during this study.

A Fisher B.O.D. incubator that could be adjusted from zero to room temperature was used to study the duration of life stages at a given constant temperature. Outside hygrothermograph records at Blacksburg from July to September were provided by Mr. R.B. Mathur.

A remodelled cardboard box tightly covered with black plastic served as a dark room for the study of effect of light. The size of this room was 25 inches long, 15 inches wide, and 20 inches high.

Eggs and larvae of different instars were preserved in AGA solution in vials. Dissected anterior and posterior portions of the larvae were dipped in 10% KOH, dehydrated with ethyl alchol, cleaned in clove oil, and then mounted on slides with Canada balsam. These slides of pharyngeal skeletons and caudal spiracles of maggots were examined microscopically. Measurements were taken through a binocular microscope equipped with a previously calibrated ocular grid.

AGA solution

| | parts |
|---|---|
| Commercial ethyl alcohol | 8 |
| Distilled water | 5 |
| Glycerine | 1 |
| Glacial acetic acid | 1 |

# RESULTS

Mating and oviposition: These observations were conducted under cabinet conditions of 25-30°C and 50-70% relative humidity as shown in Table I. One female and five to six males freshly emerged were confined in an 8 x 8 x 8 inch screened cage. Seven cages of this type were prepared. Flies were fed with a mixture of milk and sugar, clean water and blood. Fresh cow dung was available every day.

Flies were observed to start mating about 4 to 5 days after emergence. They were more active and frequently copulated at 30°C temperature. The majority of the flies mated either on the side or on the ceiling of the cage, however, "mating flight" as described by Hammer did occur occasionally. Few were observed on the cage floor.

In all cases, flies copulated in the superimposed position with the male above the female and facing in the same direction. Copulation lasted from five minutes to four hours, however, most commonly about one hour.

In contrast to Tesky's observation (1960), some females copulated two to three times with different males. This conclusion was proved by observing and marking the male flies which had previously copulated with the female in the same cage.

Flies began to lay eggs about 2 to 5 days after mating. Oviposition generally did not commence until ten minutes after arrival on the cow dung. The intervening time was spent in imbibing the dung liquids. Gravid females crept over the surface seeking a place that was soft enough for the ovipositor to penetrate. If the dung aged, and a crust began to form, females began to hunt cracks, small pits and depressions where the accumulated moisture delayed drying and hardening.

Oviposition required only a few seconds; flies extended the terminal segments of the abdomen each time an egg was laid. The flies deposited their eggs one at a time. The eggs were placed vertically into the dung. Seldom were these eggs laid fully exposed upon a flat surface. In fresh dung, they were deposited randomly over the surface. A single or batch of five to eight eggs could be found at a site.

As shown in Table I, three to seven sets of eggs were deposited by a female in her lifetime; however, four to five sets per female appeared most common. The number of eggs per set ranged from 6 to 26, but 18 to 20 eggs per set seemed to be most frequently observed. It was also recorded that females sometimes produced a set of eggs at two-to-nine-day intervals, but usually, three-to-four-day intervals. The total of eggs that a single female could produce greatly varied from individual to individual. In general, a female fly deposited 30 to 128 eggs in her lifetime.

The egg stage: The eggs (Figure 1) are provided with a long mast at the anterior end. Including the mast, the egg is about 3.0 mm long, and 0.5 mm broad. The mast is about 0.55 mm long, and 0.1 mm broad, groved on the dorsal side and generally somewhat curved at the tip. The egg shell is without visible chorion sculpture apart from a faint reticulation at the base of the mast. Two ridges run along the dorsal side of the egg and are continuous with the edges of the groove on the mast. The egg itself is yellowish white, the mast is greyish black.

Fresh cow dung packed in 10 oz. cardboard containers was introduced into the stock colony. Half an hour later, the cow dung in which hundreds of eggs had been deposited was removed and placed in controlled environmental conditions for hatching studies. Observations were made at one-hour or half-hour intervals by using microscope and magnifier. Under constant cabinet conditions, the incubation period required 16 to 18 hours; however, it took 20 to 23 hours under outside conditions (Table 2). When the eggs hatched, the larvae emerged from a slit which was formed along one of the ridges below the mast. The larvae turned and penetrated into the dung, but a few were found to creep about alone on the surface.

Eggs were removed randomly from manure with a dissecting needle after normal incubation period. Counts made on each 100-egg sample showed that the mortality of eggs ranged from 8 to 25%. Most of them were infertile eggs produced by young gravid females.

Table 1. The oviposition habits of individual females reared under constant temperature and relative humidity. a/

| Female flies | Pre-oviposition period (Days) | | Number of eggs per set b/ | | | | | | | | Total eggs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Emergence to Mating | Mating to Oviposition | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Ave. | |
| A | 4 | 2 | 18 | 19 | 24 | 17 | 20 | 12 | 18 | 18 | 128 |
| B | 4 | 2 | 11 | 18 | 14 | 20 | 16 | | | 16 | 80 |
| C | 5 | 2 | 17 | 20 | 25 | 21 | 26 | | | 22 | 109 |
| D | 4½ | 3 | 10 | 8 | 14 | 8 | | | | 10 | 40 |
| E | 5 | 5 | 3 | 15 | 12 | | | | | 10 | 30 |
| F | 4 | 5 | 16 | 13 | 6 | 17 | | | | 13 | 52 |
| G | 5 | 5 | 21 | 22 | 18 | 20 | 15 | | | 19 | 96 |

a/ Temperature 25-30°C; Relative humidity 50-70%.

b/ Batch of eggs produced by single female.

The larval stage: The larvae are of normal muscoid shape, tapering off gradually to the anterior end from the middle region, and with the posterior end truncate. The body is conically cylindrical with twelve apparent body segments and without appendages (Figure 2). The first or pseudocephalic segment is short and conical; ventrally, it is armed with a pair of mouth hooks (Figures 8, 9, 10). The cephalopharyngeal skeletons are sclerotized structures, located at the anterior end of the alimentary canal (Figure 9). They include the mouth hooks (MH), the dentate sclerites (DS), the ligulate sclerites (LS), the hypostomal sclerites (HS), and the pharyngeal sclerites (PHS). The pharyngeal sclerites are two lateral sclerotized plates incised deeply posteriorly so as to form pairs of well pronounced ventral cornua (VC) and dorsal cornua (DC). The parastomal sclerites are entirely missing in this insect. At the beginning of the second stage, there appears at the first thoracic segment, in the lateral position, a pair of anterior spiracles which bear seven to nine finger-like openings. The first two segments of the larvae are not provided with spines. From the fifth to the twelfth segment, there is a transverse locomotor pad provided with a spinose ring. Complete spinose rings appear on the third to seventh segment; incomplete spinose rings are found on the eighth to twelfth segment. Each ring is composed of five to seven rows of spines and is situated on the anterior margin of the segment. The last segment is the largest,

with a well sclerotized plate surrounding both lateral and ventral surfaces (Figure 3). The anus is situated on the rear part of its ventral surface between a pair of anal protuberances (AP). There are five short rows of spines posterior to the anal opening. The posterior surface is rather flush; close up to the dorsal margin, there is a depression in which the posterior spiracles are located. A number of smooth tubercles are found around the posterior surface; one on the upper; two on the lateral, and four on the lower portion of each side (Figure 3).

There are three instars, each of which differs characteristically in detail of the cephalopharyngeal skeletons and the spiracles.

First instar: The average measurements of the larvae are 3.0 mm in length and 0.6 mm in width. The body is whitish with black sclerotized spines and without anterior spiracles. The cephalopharyngeal skeleton (Figure 8) is 0.47 mm long and 0.22 mm broad, and does not have definite dentate sclerites and ligulate sclerites. Instead there are two long and slender rods connecting the pharyngeal sclerites to the hypostomal sclerites. The lateral plates of pharyngeal sclerites are narrow, slender and pointed at the end of both ventral and dorsal cornuas. There is no ventral connection of the lateral plates. The dorsal bridge (DB) is broader in the middle. The posterior spiracles (Figure 5) are bifurcate in shape, partly divided dorso-ventrally into two rounded lobes in the outer margins. Dorsal tracheal trunks are broader near the

spiracular openings, a fringe of fine hair surrounds the inside surface of the trunks.

Second instar: The larvae are 5.0 mm to 6.7 mm long ( av. 5.8 mm), and 0.75 mm to 1.25 mm broad ( av. 1.0 mm), and the prothoracic segment bears a pair of anterior spiracles. Spines are unsclerotized and colorless. The cephalopharyngeal skeletons are about 0.8 mm long and about 0.32 mm high. The oral hook is paired in equal size; the angular sclerites (AS) and ligulate sclerites (LS) are present in this instar. The lateral plates of the pharyngeal sclerites become considerably broader and are connected by the ventral bridge (VB) and the dorsal bridge (DB). The dorsal bridge is broader in the middle and perforated. The posterior spiracular plates (Figure 6) are D-shaped; poorly sclerotized with no peritreme; 0.17 mm long, and 0.15 mm broad. There are two slits, relatively broad and winding, in each plate. The button is not distinct.

Third instar: The larger body (8.0 mm to 13.7 mm in length and 1.5 mm to 2.5 mm in width) (Figure 2) and longer cephalopharyngeal skeletons (1.5 mm in length, 0.5 mm in height) (Figure 7) distinguish this instar. The oral hooks are composed of two hooks, of which the right is strong and conspicuous while the left is small and reduced. The dentate sclerites bear seven to eight teeth antro-ventrally. The

hypostomal sclerites are shorter but broader, and the pharyngeal sclerites are elongate and broader. The posterior spiracular plates, 0.35 mm long and 0.28 mm broad (Figure 7) are D-shaped with straight inner margins. The spiracular plates are heavily sclerotized and lack a distinct peritreme. Each plate has three sinuous slits that are relatively long, narrow and winding. The body of this stage becomes slightly yellowish and eventually turns yellow in the full-grown larvae prior to pupation.

The duration of each instar was determined under constant temperature at 25-30° C and 50-70% relative humidity. The duration of the first instar was 6 1/2 to 7 1/2 hours, 16 1/2 to 17 1/2 hours for second instar, and 55 to 57 hours for third instar. The total duration of the larval stadia ranged from 78 to 82 hours. Newly hatched larvae were sluggish, tunnelling just beneath the surface of the rearing media. The second and third instar larvae began to burrow throughout the whole media. Full-grown larvae had a tendency to move away from the rearing media or to migrate to the crust of the media which was dryer. All the larvae were negatively phototrophic, they tried to hide themselves either in the rearing media or in a shelter. Mortality of the larval stage under laboratory conditions ranged from 18 to 28%.

## EXPLANATION OF PLATE I

The morphological characteristics of immature stages of the face fly.

Figure 1. The egg.

Figure 2. The full-grown larva.

Figure 3. Posterior view of the full-grown larva.

Figure 4. The pupa.

Figure 5. The posterior spiracles of the first instar larva.

Figure 6. The posterior spiracles of the second instar larva.

Figure 7. The posterior spiracles of the third instar larva.

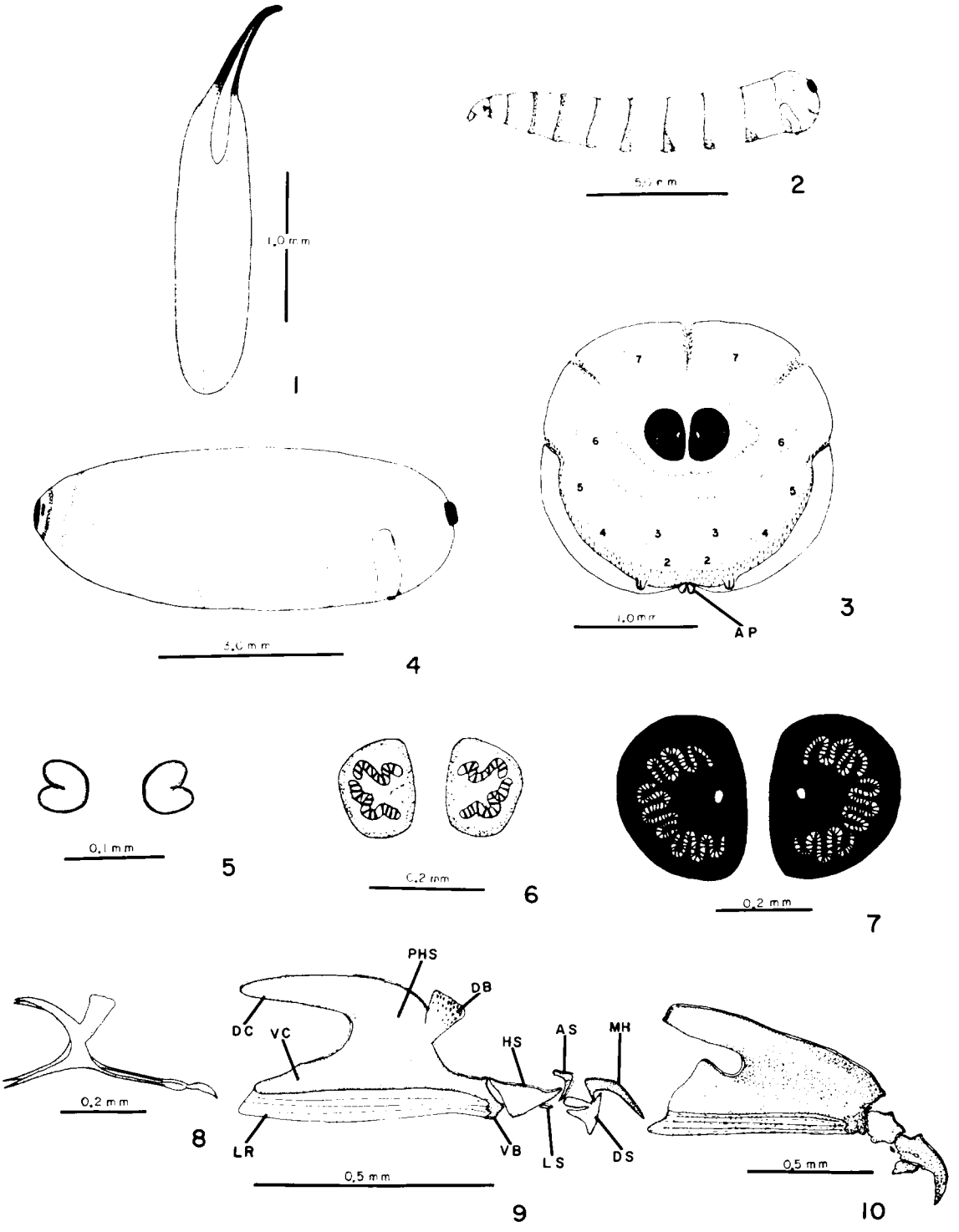
Figure 8. The cephalopharyngeal skeleton of the first instar larva.

Figure 9. The cephalopharyngeal skeleton of the second instar larva.

Figure 10. The cephalopharyngeal skeleton of the third instar larva.

Abbreviation: AP, anal protuberance; AS, angular sclerite; DB, dorsal bridge; DC, dorsal cornua; DS, dentate sclerite; HS, hypostomal sclerite; LR, longitudinal ridge; LS, ligulate sclerite; MH, mouth hook; PHS, pharyngeal sclerite; VB, ventral bridge; VC, ventral cornua.

# PLATE I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7
PHS
DB
DC
VC
HS
AS
MH
0.2 mm
8
LR
VB
LS
DS
0.5 mm
9
0.5 mm
10

The pupal stage: The pupa is enclosed within a puparium which is shorter but broader than the third instar larvae. In a normal specimen, the puparium is cylindrical, 6.5 mm long and 2.6 mm broad, bluntly rounded at both ends with the anterior end slightly tapering. The anterior spiracles are situated almost at the anterior end, the posterior plates are represented by two flat, button-like prominences at the posterior end. The deposition of spines on the puparium is similar to that on the larva. Newly pupated puparia are yellowish; later they become dirty white and turn grey prior to emergence.

The full-grown larvae started wandering a few hours before pupation. In general, the pupation process was completed in one hour. The duration of the pupal period was observed to be 7 1/2 to 8 days under constant temperature ranging from 25 to 30° C and 50 to 70% relative humidity. The pupal mortality ranged from 20 to 35% under these conditions.

The adult stage: The aduly fly has been first described by Austen (1926), then by Patton (1933) and van Emden (1939). The following descriptions are condensed from these authors and Vockeroth (1953).

M. autumnalis DeG. is a bulkier, more compactly built and thick set insect in comparison with the house fly. In a normal specimen, it is larger than the house fly (6 mm to 7 mm in length, West, 1951), measuring 5.6 mm to 6.8 mm long and 2.2 mm broad in the male;

7 mm to 8 mm long and 2.0 mm to 2.5 mm broad in the female.

Male: The compound eyes are bare and separated by less than the width of the ocellar triangle, and appear to be almost or actually in contact at one spot; the ground color of mesonotum is bluish-grey, lightly pollinose, with four broad black stripes; the abdomen has a black base, from which there is a backward prolongation, the median stripe that is blackish in color; the remainder is orange-brown.

Female: The vertex is wide, almost the width of an eye; the orbital stripe is grey and pollinose, at least one-half as wide as the black median frontal stripe; the mesonotum is grey with four broad black stripes; the abdomen is silvery black above; the ventro-lateral region of the base is dark orange; terga 3rd and 4th has a narrow median black stripe, and the sterna are black and pollinose.

The emergence of the adult flies from the puparium occurred mostly in the early morning. It required at least one hour to complete transformation, and to become active after emergence. The young flies were excitable and did not start to feed until they were two days old. During this time, they simply imbibed water that was provided. The flies were strongly photo-positive, crawding over the screen surface facing the light source. In screened cages, they preferred running and creeping rather than flying. The longevity of adult flies ranged from three weeks to three months under controlled temperatures rang-

ing from 25 to 30°C and 50 to 70% relative humidity; however, four to eight weeks was observed to be the average longevity for the majority of the flies. Both sexes had equal longevity. The overall duration of development from egg to adult required about 11 1/2 days to 12 days under the constant temperature and relative humidity conditions mentioned above.

# THE EFFECTS OF TEMPERATURE AND HUMIDITY ON DEVELOPMENT AND BEHAVIOR

Temperature and relative humidity are believed to be two important environmental factors which strongly effect the life processes and behavior of all life stages of the face fly. The following observations were made to ascertain the effects of these factors on the face fly under laboratory conditions. The range of temperatures utilized in these observations were between 0 and 40° C. The outdoor conditions of Blacksburg, Virginia, during July and August were: temperature, 9-35°C; and relative humidity, 32-96%. The rearing media were pre-heated or pre-chilled prior to the experiment depending on the temperature to be used in the particular test. The relative humidity in the laboratory varied from 50 to 70% and was kept as constant as possible under the different temperatures used in the experiment. The beginning of each stage was recorded at certain intervals. The test specimens were checked with microscope and magnifier in order to record the duration of each stage.

As cited by West (1951), in the house fly, the egg is more sensitive to abnormally high temperatures than the larva, and the larva is more sensitive to abnormally high temperatures than the pupa. The egg appears to be least resistant to cold, whereas the adults are most able to survive at low temperatures.

The eggs of M. autumnalis DeG. failed to develop when exposed to 11°C. The optimum temperature for egg development appeared to be between 35 to 40°C (Table 2). The rate of development at optimum temperature was approximately twice as fast as at 20°C. High moisture in the rearing media seemed to be desirable for egg development and survival. The high desiccation and rapid formation of a crust on the surface of the media caused shrinkage and thus a cessation of development of the egg.

The duration of the larval stages is shown in Table 2. Larvae survived at 0°C; however, they did not undergo further development. In this case, larvae moved slowly and tended to concentrate at the center of rearing media. Complete larval development took 21 days at 11°C; however, only 2 1/2 days were needed to complete larval development at 35 to 40°C. Thus, it is reasonable to predict that the optimum temperature is approximately 40°C. It was also observed that moist media favored the activity of younger larvae, and the full-grown larvae preferred dryer media. Amounts of moisture higher than the usual water content in manure proved fatal to the larvae in any instar.

Pupae could not tolerate the cold, and were killed after exposure at 11°C for a week. The duration of development at 20°C appeared approximately equal to that of outdoor conditions. The optimum temperature for pupal development, like egg and larva, ranged from 35 to 40°C.

Adult flies could withstand the cold. It was found that adults survived at 0°C for at least a week. The flies tended to be more active as the temperature increased from 25 to 40°C. It was also observed that the feeding, mating, and oviposition activities superseded during this range of temperature. High relative humidity was also able to affect fly activity. When relative humidity was increased over 80%, activity decreased; and if humidity was increased over 90%, the flies were found to be sluggish and weak. Feeding, mating, and oviposition activities ceased.

Table 2. The effect of temperature on the duration of each stage of the life cycle. Blacksburg, Va., 1962.

| Temperature (C) | Life Stage | | | | | | |
|---|---|---|---|---|---|---|---|
| | Egg (hrs.) | 1st. instar larval (hrs.) | 2nd. instar larval (hrs.) | 3rd. instar larval (hrs.) | Total larval period (days) | Pupal (days) | Total cycle-egg to adult (days) |
| 0 | killed | alive a/ | alive | alive | alive | killed | - |
| 11 | killed | 48 | 96 | 360 | 21 | killed | - |
| 20 | 21-22 | 21-22 | 24 | 75 | 5 | 11½-12½ | 17½-18½ |
| 25-30 | 16-18 | 7-8 | 16½-17½ | 55-57 | 3-3½ | 7½-8 | 11½-12 |
| 30-35 | 10-11 | 8 | 10-11 | 52 | 3 | 5½-6 | 9-9½ |
| 35-40 | 9-10 | - | - | - | 2½ | 4½-5½ | 7½-8½ |
| Outdoor b/ | 20-23 | 9-10 | 20-22 | 84 | 4½-5 | 11-12 | 16½-18 |

a/ Larvae remained alive during the period of study, but did not develop any further.

b/ Outdoor temperature during July and August: 9-35°C; relative humidity: 32-96%.

3 da.

## THE EFFECT OF DIET ON OVIPOSITION

As described by West (1951), the food of the adult house flies is important in two ways: first, it is to sustain the life of the individual; and, second, it must provide for the maturation of the sex organs. The conclusions of numerous workers indicate that carbohydrate is necessary for longevity, and protein is necessary for maturation of the ovaries on the house fly (Glaser, 1923; Kobayashi, 1934; Derbeneva-Ukhova, 1935). This conclusion might also apply to M. autumnalis DeG. reared under laboratory conditions.

It was observed that sugar and milk appeared to be two vital nutrients for the adult face fly. Bovine blood played an important role in stimulation of egg-production, as indicated in Tables 3 and 4. This shows that the females that were fed with sugar-milk mixture plus bovine blood laid more eggs than did the females fed with sugar-milk mixture only. These results also indicated that a bovine blood diet accelerated sexual maturation, but did not influence the adult longevity.

Table 3. The effect of bovine blood diet on sexual development and oviposition of adult face flies under constant temperature and relative humidity conditions a/. Blacksburg, Va., 1962.

| Diet | No. days from emergence to mating | No. days from mating to oviposition | No. eggs per female | Adult longevity (days) |
|---|---|---|---|---|
| With blood | 4-5 | 2-4 | 80-128 | 22-50 |
| Without blood | 4-6 | 3-6 | 30-80 | 30-55 |

a/ Temperature 25-30° C; relative humidity 50-70%.

Table 4. The effect of bovine blood diet on sexual development and oviposition of adult face flies caged under natural outside conditions a/, Blacksburg, Va., 1962.

| Diet | No. days from emergence to mating | No. days from mating to oviposition | No. eggs per female | Adult longevity (days) |
|---|---|---|---|---|
| With blood | 4-6 | 5-6 | 40-105 | 30-55 |
| Without blood | 5-8 | 5-8 | 30-40 | 30-50 |

a/ Cages placed outside during July and August 1962; temperature range 9-35°C, relative humidity 32-96%.

# THE EFFECTS OF LIGHT ON SEXUAL DEVELOPMENT AND OVIPOSITION

Preliminary observations on the effects of light on the face fly were made under laboratory conditions at 25 to 30°C and 50 to 70% relative humidity. A Standard Sun Lamp of 275 watt was set up three feet from the cage that confined the flies. All the test flies were fed with sugar-milk mixture plus bovine blood, and were separated into three groups. Each group was composed of one female and three male flies. The first group received 8 hours of illumination per day, the second group 16 hours, and the third group received 24 hours. The results were obtained by observation and counting the number of eggs daily. The whole experiment was repeated two times.

Data shown in Table 5 indicate that light definitely influence sexual development and oviposition, not only increasing egg-laying, but also accelerating sexual maturation.

Table 5. The effect of light on sexual development and oviposition of adult face flies under constant temperature and relative humidity conditions a/. Blacksburg, Va., 1962.

| Illumination b/ (hrs./day) | No. days from emergence to oviposition | No. eggs per female |
|---|---|---|
| 8 | 8 | 30-35 |
| 16 | 6 | 60-80 |
| 24 | 5 | 128 |

a/ Temperature 25-30°C; relative humidity 50-70%.

b/ Standard Sun Lamp 275 watt, 3 feet from the cages.

# DISCUSSION

Since its discovery in 1952, M. autumnalis DeG. has become a new pest on this continent. The morphological characteristics of this insect makes it possible to distinguish it from related muscoid flies. The characteristics of this fly are summarized as follows: Eggs are provided with a long, greyish black mast, and are without chorion sculpture. The larvae possess characteristic cephalopharyngeal skeletons, heavily sclerotized posterior spiracular plates, and seven pairs of smooth tubercules on the posterior surface. The puparium is white. The adult flies are similar to the house fly in general appearance, but there are detailed differences to separate these two species.

Adult flies are facultative haematophagous, feeding on nectar, animal secretions, and dung liquid. From the nutritional standpoint, neither carbohydrates nor protein as food can singly meet the requirement for sexual development; however, the combination of these two nutritional elements appears to provide a complete diet for the flies. Nectar is rich in carbohydrates. Cow manure is only one source of nitrogenous substance. The main component of animal secretion is mucoprotein which consists of both protein and carbohydrate. Bovine blood contains a high amount of protein, which may be rich in ingredients more utilizable by the female flies, thus, it gives rise to significant

ovary development. Since the face fly can make use of a variety of food sources, it is not surprising that this insect is widely spreading in this country.

Each stage of the life cycle has its maximum and minimum temperature for bodily activity. The optimum temperature is usually closer to maximum than to the minimum; therefore, the optimum temperature for the life cycle of the face fly is considered to be somewhere in the vicinity of 40°C, though there is not an exact point for any stage.

West (1951) mentioned that the pupation of the house fly always takes place at lower temperatures than those favored by the larvae. This fact explains partly the cause of migration in full-grown larvae; however, the effect of moisture is considered to be another cause.

Mention has already been made of the fact that the majority of adult face flies emerged in the early morning both in the controlled environment and under outside conditions. A possible explanation for this is based on the conclusion made by Pittendrigh (1954). He stated that the emergence of adult Drosophila occurs in bursts in the hours following dawn. He also stated that emerging flies lose water at a rate at least double that of mature flies, and fail to expand their wings properly when the humidity is too low. Thus, it is clear that there is a definite adaptive significance which restricts the emergence activity of the flies to the coolest and most humid hours of the day. Since the

hours following dawn, in general, are the coolest and wettest hours of the day, the emergence of adult face flies could be similar to that of Drosophila.

From the results obtained, it was indicated that adult flies were more resistant to low temperature than pupae, thus accounting for the fact that the adults are observed hibernating in the winter.

Frequency of feeding is believed to be an important factor in determining the rate of development and reproductive potential. In case of the short period of illumination, the adult flies received limited light stimulation, and fed less frequently; therefore, the poor reproduction of the fly may partly be ascribed to malnutrition.

# SUMMARY

1. Under laboratory conditions (25-30° C) face flies that were fed with citrated bovine blood started to mate about 4-5 days after emergence. Oviposition began 2-5 days after mating.
2. Adult flies were observed to copulate more than one time during their life span. Some females copulated with up to three different males.
3. Longevity of adult flies ranged from three weeks to three months. The egg-laying ability lasted throughout their lifetime.
4. The number of eggs per female varied greatly, depending upon diet, light, and temperature. In general, 30 to 128 eggs per female were recorded.
5. Mortality of the eggs ranged from 8 to 25% with an incubation period of about 16-18 hours at 25-30°C.
6. There are three larval instars in the face fly. The duration of each instar varied considerably with the temperature and was observed to be about 3-3 1/2 days at temperatures of 25-30°C. Larval mortality under laboratory conditions appeared to be 18-28%.
7. Full-grown larvae had a tendency to leave the manure to find a proper place for pupation. The transformation from larva to pupa was sometimes completed within one hour. The pupal period at room temperature required about 7 1/2 to 8 days, and the mortality ranged from 20 to 35%.

8. At 11°C, both eggs and pupae were killed; however, the larvae survived even at 0°C.
9. In a constant temperature cabinet, the optimum temperature of each life stage appeared to be approximately 40°C.
10. Under laboratory conditions (25-30°C), the total cycle of egg to adult was 11 1/2 to 12 days and under natural conditions during July and August, the duration from egg to adult was 16 1/2 to 18 days.
11. Sugar and milk appeared to be two vital nutrients for the adult fly; however, bovine blood was found to be most important in increasing sexual maturation and egg production.
12. The effect of light on sexual development and oviposition was also found to be important. Increased illumination resulted in acceleration of sexual maturation and increased egg production.

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Credit is due to for typing this manuscript.

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## ABSTRACT

A laboratory study on the face fly reported herein was conducted at Blacksburg, Virginia, from July through September, 1962, to ascertain the biology of each stage of the life cycle, and to determine the relationship of certain environmental factors on the fly activity under laboratory conditions.

Morphological descriptions of each life stage were made in order to distinguish this insect from other related muscoid flies.

Temperature and humidity were found to be two essential environmental factors which influenced the development and activities of the face fly. Rate of development in each stage under different ranges of temperature was emphasized. Similarly, observations were also made to determine the characteristic behavior of both larvae and adults in response to these environmental factors.

Little has been published on food habits of this insect; thus, emphasis was laid on a study of the effect of diet on sexual development and reproduction. Results obtained have shown that sugar and milk appeared to be two vital nutrients for the adult fly, and that bovine blood could increase sexual maturation and egg production.

Considerable attention was also given to the relationship between illumination and sexual development and reproduction. It was found that increased illumination resulted in acceleration of sexual maturation and increased egg production.