Medical and veterinary entomology

William Brodbeck Herms

MEDICAL AND VETERINARY ENTOMOLOGY

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MEDICAL AND VETERINARY ENTOMOLOGY

A TEXTBOOK FOR USE IN SCHOOLS AND COLLEGES
AS WELL AS A HANDBOOK FOR THE USE OF
PHYSICIANS, VETERINARIANS AND
PUBLIC HEALTH OFFICIALS

BY

WILLIAM B. HERMS

ASSOCIATE PROFESSOR OF PARASITOLOGY IN THE UNIVERSITY OF CALIFORNIA, CONSULTING
PARASITOLOGIST FOR THE CALIFORNIA STATE BOARD OF HEALTH, AND
FORMERLY PROFESSOR OF ZOÖLOGY AND PARASITOLOGY IN
THE SAN FRANCISCO VETERINARY COLLEGE

AUTHOR OF "MALARIA, CAUSE AND CONTROL," "A LABORATORY GUIDE TO THE
STUDY OF PARASITOLOGY," "THE HOUSEFLY IN ITS RELATION TO THE
PUBLIC HEALTH," "HOUSEFLY MANAGEMENT," ETC.

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Dedicated to

MY STUDENTS IN PARASITOLOGY

PREFACE

Much of the matter contained in the following pages was prepared for the press more than six years ago, but owing to the rapid advances made in the field of parasitology, particularly concerning insects, the writer has withheld it until this time, when, after considerable revision and addition, it has seemed expedient to publish the same. The manuscript has been in almost constant use for a period of six years in teaching classes in Parasitology, both in the University of California and in the San Francisco Veterinary College. It has been the aim to include herewith a large part of the writer's original work, some of which has until now remained unpublished, as well as the published observations of many other investigators in this field, all of which has gone to build up the foundation of the new science of ***Medical Entomology***.

This book is not intended to be a comprehensive treatise, touching all the investigations in the field of Medical Entomology, but rather an attempt to systematize the subject and to assist in securing for it a place among the applied biological sciences. However, a discussion is included of all of the more important diseases and irritations of man and of the domesticated animals in which insects and arachnids are concerned, either as carriers or as causative organisms.

Owing to the immense literature on insects as relating to disease, much of which is widely scattered, the student in this field must spend considerable time in searching for the desired information, and what is more important, the information is not readily accessible to the physician, the veterinarian, the health officer and the sanitarian. It is therefore to be hoped that this book will not only prove useful as a text, but also as a handbook for all individuals who are professionally interested in the health and well-being of man and beast, as affected by insects and arachnids.

In the second place detailed accounts of experiments are included here and there, so that the investigator might employ the methods described in either the repetition of the work or in carrying on further investigations along the lines suggested.

Although many special papers have been consulted in the preparation of this work, a bibliography is not included herewith, inasmuch as this information is obtainable in much more complete form in the bibliographical works of other writers. Reference to special papers is usually made in footnote form, but where certain facts have long been accepted as common knowledge, reference is ordinarily omitted.

Sources from which assistance has been drawn are too numerous to adequately enumerate, but to all who have contributed toward the preparation of this work I wish to express my sincere appreciation and thanks, but most particularly to my advanced students in parasitology, who have contributed much valuable data, and to my colleagues, Professor C. W. Woodworth, Dr. Edwin C. Van Dyke, Dr. W. A. Sawyer, and Mr. S. B. Freeborn, and to my wife, Lillie M. Herms, who have at all times given generous coöperation and kindly criticism.

Unless otherwise credited the illustrations are from photographs and drawings made by the author and various assistants. Thanks are due particularly to Dr. William Colby Rucker for the use of flea drawings, to Professor Herbert Osborn for permission to reproduce certain drawings of biting and sucking lice, to M. B. Mitzmain for photographs of *Tabanas striatus*, to Prof. J. S. Hine for photographs of certain other Tabanids, and to Mr. W. C. Matthews, Scientific Illustrator, for valuable assistance in the preparation of many of the figures.

W. B. H.

Berkeley, California.

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MEDICAL AND VETERINARY ENTOMOLOGY

CHAPTER I

INTRODUCTION

Scope and Methods. — Medical Entomology is concerned with the study of insects and arachnids as they relate to the transmission and causation of disease in man and beast, and is, therefore, a specialized branch of the science of Parasitology. Mosquitoes and flies have for centuries past been looked upon as a source of extreme annoyance to the human family, and students of animal husbandry and of veterinary medicine early recognized the importance of lice, flies and ticks as sources of irritation to horses, cattle, hogs, etc. But that insects and arachnids could be transmitters of disease was not considered seriously until the latter part of the last century, and that certain species could be the *sole* transmitters of specific diseases was scarcely suspected until the latter few years of the past and the beginning of this, the twentieth, century. To-day our knowledge of disease transmission by insects has been greatly augmented by the work of a host of individual investigators representing various departments of scientific research, such as Medicine, Veterinary Medicine, Bacteriology, Hygiene, Zoölogy and Entomology.

The usual training received in any one of the departments above mentioned is necessarily of such a nature as to handicap any one undertaking health problems in which insects and arachnids are concerned. Therefore, to meet the ever growing demand for investigators in this rich field, and to satisfy the question of responsibility, the science of Medical Entomology has been evolved. This science shares a portion of the fields of Pathology, Bacteriology and Entomology; the first, in that certain phases of pathology are involved; the second, in that pathogenic bacteria and protozoa are concerned; and the third, in that the systematic and biological relationships of the insect must be studied as well as the morphology of its mouth parts and digestive system. For example, in the study of malaria, blood corpuscles are involved, calling for a knowledge of both normal and diseased human blood; an intimate knowledge of blood parasites is imperative; and the insect host, the Anopheles mosquito, must receive particular attention, as to its identification, anatomy and habits. It is evident at once that a knowledge of the details of these three phases requires a specific training.

The ultimate aim of the science of Medical Entomology is the prevention of diseases in which insects are concerned; it is therefore an important adjunct to Preventive Medicine and Public Health.

Notable instances where the control of certain diseases has depended upon the control of insects are, as is well known, the mosquito campaigns of Cuba, Panama Canal Zone and the southern United States to control yellow fever mainly, and in New Jersey, California, Italy and portions of Africa to control malaria. Lately much attention has been paid the common house fly; inasmuch as it has proved a gross carrier of certain enteric or intestinal diseases, campaigns of considerable proportions have been waged against this insect in many American cities from the Atlantic to the Pacific. One of the most notable examples of preventive work is that accomplished in San Francisco in the control of rats and rat fleas, thereby exterminating bubonic plague in that city and preventing its spread.

The very close bond between Preventive Medicine and our present subject is at once evident, and its significance becomes more and more apparent as men devote themselves to this highly fertile field of investigation.

Economic Considerations. — In this age of universal progress, efficiency has been made the keynote, and losses traceable to disease are now estimated very closely on a money basis. Even human life is given a definite monetary valuation. Thus the California State Board of Health has estimated that malaria costs the state of California $2,820,400 annually, and this state is largely free from that disease. An attempt to estimate the loss due to malaria in any one of the intensely malarial states of the South, would produce staggering results.

The above sum is based on the following items, viz., death of 112 citizens, average value $1700; 6000 acute cases of malaria at an average of $20 per year for drugs, etc.; 6000 citizens' earning power reduced 25 per cent by malaria (estimated average income $800); loss of life, wages and illness from other diseases given opportunity through lowered resistance brought about by malaria, estimating 50 deaths at $1700, and 1000 persons ill at $100 each; loss through sacrifice sales of farms and moving expenses of families leaving malarial districts, estimating 250 families at $500; loss through depreciation in land values, estimating $1 per acre only on 1,000,000 acres under irrigation in parts concerned. Nearly or quite all of this loss could be prevented by mosquito control efforts.

Reduction in value of real estate in mosquito-infested regions is quite unnecessary. Otherwise very desirable agricultural land is often made unproductive because of hordes of mosquitoes attacking man and beast; and again otherwise desirable locations for summer homes are made uninhabitable because of the mosquito nuisance, — all of which could be remedied at a comparatively small cost. Real estate dealers have hardly begun to avail themselves of the services rendered by the study of these conditions.

The expense incurred in the United States in the purchase of fly traps, sticky fly paper, fly poison, etc., must certainly exceed two millions of dollars annually, and Howard,[1] in a timely work on the economic loss due to insects that carry disease, estimates the cost of screening at over ten millions of dollars per annum.

As affecting the animal industry equally large losses are involved. According to the year book of the United States Department of Agriculture for 1904, the losses occasioned by Texas fever, solely transmitted by a tick (*Margaropus annulatus*), amounted to about $100,000,000. Ransome, in *Tanners' Work* for October, 1913, estimates the total loss produced by the 'ox warble fly' (*Hypoderma lineata*), at from $55,000,000 to $120,000,000 per year for the United States alone.

No effort has been made to estimate the losses caused by the Texas screw worm and the horn fly as affecting cattle, the former producing a direct loss, while the latter produces largely an indirect loss due to irritation, involving loss of flesh, poor growth, reduction in milk secretion, etc.

To poultry raisers the losses due to the fowl tick (*Argas persicus*) and the poultry mite (*Dermanyssus gallinæ*) must also be quite considerable.

Control of Insect-borne Diseases. — Manifestly the control of insect-borne diseases depends on two general conditions. The first is the control of the focus, through which the insect becomes infected, the insect being commonly only a carrier, and not a permanent receptacle. In the case of certain infectious diseases in which the germ is found in the dejecta, *i.e.* feces and sputum, proper sanitary precautions are imperative; thus properly constructed fly-tight privies prevent in large measure the transmission of typhoid and dysentery by flies; the use of paper sputum cups (cups to be burned) and fly-tight cuspidors by victims of tuberculosis prevents in large measure the spread of this disease by flies. The rigid enforcement of "anti-spitting" laws and ordinances regulating the construction of privies will bring about good results. Again, proper regulations requiring patients known to be ill with insect-borne diseases to be screened against insects, prevent wholesale infection. Thus yellow fever quarantine is imperative in order to prevent the mosquito carrier (*Aedes calopus*) from becoming infected. If such regulations were applied to malaria, there would be much less of this disease. However, in this latter case, quarantine would cause much hardship, because the patient may not be ill enough to require close confinement, and yet there is every opportunity to infect the Anopheline carrier. A further element of importance enters in, namely immunity, under which condi-

[1] Howard, L. O., 1909. Economic loss to the people of the United States through insects that carry disease. U. S. Dept. of Agr., Bureau of Entomology, Bull. No. 78.

tion the infected carrier is not a menace, as in the case of yellow fever.

The second factor in the control of insect-borne diseases is the practical extermination or control of the carrier, *i.e.* the insect. This is the safest and surest method.

Insect Control. — In the control of disease-transmitting insects, the most vulnerable point in the life history is sought, and the most effective combative methods are then applied. This involves an intimate knowledge of life history and habits. The more familiar we are with regard to these two factors, the better equipped are we to cope with the problems of control.

The application of control measures may be either of a temporary or permanent nature. Temporary control involves the elimination of a nuisance for a short time, a few hours or a few days, requiring constant repetition; for example, the use of formaldehyde to kill flies, or pennyroyal or citronella to repel mosquitoes, or even oil as applied to mosquito-breeding pools. Permanent control, on the other hand, involves the elimination of breeding places, or permanent protection of the same by mechanical or chemical means, to prevent the deposition of insect eggs, for example, draining or filling up unnecessary ponds and pools of standing water, in which mosquitoes may breed; or placing horse manure and general refuse in receptacles made fly-tight in order to forestall the breeding of house flies.

Permanent control measures, when feasible, will always be far less expensive in the end, and also very much more effective than the use of temporary agents in the form of insecticides, which must be applied over and over again, with continuous expenditure of time, labor and money. Standing water can often be drained off with little expense, whereas the repeated application of oil must eventually involve greater outlay and inconvenience. To illustrate, the writer at one time observed a small pond which was surely furnishing most of the mosquitoes for the neighborhood; it was the only pond near, and was within ten feet of a rapidly running stream lower in elevation than the pond by at least eighteen inches. This pond could have been drained very easily and would have resulted in permanent prevention; however, oil was being applied regularly. The pool was evidently of no use to any one, and was within the limits of a mosquito campaign. Again, the common house fly, a source of so much annoyance, is ordinarily combated with poisons, sticky fly paper and screens, when the mere removal of perhaps a single horse manure pile in the immediate vicinity would speedily give ready and permanent relief.

Field Observations. — In the practical control of insects the observations made in the field are indispensable to the correct interpretation of laboratory or clinical observations. A parasite removed from its normal host and brought under unnatural conditions may not function normally, the reproductive function is commonly disturbed, few or no eggs being deposited in captivity, or if so, they may not be fertile. Therefore, it is far preferable to carry on observations where life history is concerned in the field or under fairly natural conditions.

Popular Opinion. — A crusade against disease-transmitting organisms such as insects always brings with it a storm of opposition on the part of not a few people, who contend that it is a breach of trust with Nature to proceed against any species already in existence. Few ideas are more firmly rooted in the mind of the average man or woman than that Nature has brought forth nothing that is useless in the economy of the human family. It must be good for something, otherwise it would not be in existence, and should, therefore, not be exterminated or even molested. True it is, that we must study Nature's ways and endeavor to find out what she is trying to do, then help her carry out her plans more quickly and more accurately. For instance, if Nature has provided scavengers, she is endeavoring to clean up, thus pointing out to man what he should do. The house fly is often spoken of as one of Nature's scavengers. By a careful study of the performance of this function by the fly, it can be determined without question that this insect is a very poor scavenger, and that this function is carried on better by other insects (*e.g.* certain flesh flies) which do not commonly relate to human food as does the house fly, if indeed this argument should be necessary. Certainly no one would contend that it is necessary to be infested with vermin as a substitute for bodily cleanliness, and surely no one would argue that it is a breach of trust with Nature to annihilate the Anopheles and Stegomyia mosquitoes, the transmitters of malaria and yellow fever respectively.

CHAPTER II

PARASITES AND PARASITISM

Parasitism. — It is well that a distinction be made at this time between parasitic and predaceous insects, though the two groups will not remain distinct throughout all species, since the beginnings of parasitism may not be readily distinguishable from the predaceous habit. It is evident that a parasite can only be a parasite as it lives directly at the expense of another organism, whether plant or animal. This definition, however, leaves few animals, if any, out of the category, inasmuch as the dependence of animals directly on other animals or plants for food is obvious. But if we restrict this meaning to position, living *in* or *upon* another animal or plant for purposes of food, we come nearer to the thought. But even here there are many organisms which live in or upon living animals or plants, but merely *share* their food with them without causing injury, — this we would term *commensalism*. Furthermore, organisms feeding in or upon dead bodies would not be termed parasites, except as they also attack or feed on living tissue, as in the case of certain flesh flies, *e.g.* the Texas screw worm fly (*Chrysomyia macellaria* Fabr.), which as a larva may feed on the flesh of either dead or living animals. Parasitism, then, involves the process of one organism (the parasite) feeding upon another living organism (the host), which host must not be destroyed before at least the developmental or larval period of the parasite is completed, otherwise the result would be disastrous to the parasite as well as to the host.

The definition given by Braun[1] is "By the term Parasites is understood living organisms, which for the purpose of procuring food, take up their abode, temporarily or permanently, on or within other living organisms." This definition will exclude predaceous animals (*Raubtiere*), which capture their prey alive and usually kill it outright for purposes of food.

Classes of Parasites. — Other than the two general classes, *Ectoparasites* (external parasites) and *Entoparasites* (internal parasites), all parasites may be placed in one of the following divisions, according to the *time* spent on or within the host. *Facultative* parasites have the power of changing from one host to another of a different species, *e.g.* the cat and dog flea (*Ctenocephalus canis* Curtis) which may be found

[1] Braun, Max, 1905. The Animal Parasites of Man. William Wood and Company, New York. xviii + 453 pp.

on the cat, the dog, the rat and man; the rat flea (*Ceratophyllus fasciatus* Bosc.) on the rat and man; the wood tick (*Dermacentor variabilis* Say) may be found on nearly all species of domesticated mammals and man. *Obligatory* parasites are restricted to one species of host, on which they are obliged to remain throughout their life history, *e.g.* the biting bird lice (Mallophaga), which perish if removed from the host or if transferred to another species of animal. *Intermittent* parasites prey on the host at intervals, coming only to feed, after which they leave again, *e.g.* female horseflies (Tabanidæ) in their relation to horses and cattle; or the bedbug (*Cimex lectularius* Linn.) in its relation to man. *Transitory* parasites pass only part of their life history at the expense of a given host and are, during that time, obligatory, *e.g.* the horse botflies (*Gastrophilus equi* Fabr.), which pass their larval or developmental period within the stomach of the host, the adults being free-living; or in other transitory parasites the remaining portion of the life history may be spent at the expense of an entirely different species of host, as is the case in tapeworms.

Effect of Parasitism on the Host.—That an animal is parasitized does not necessarily involve it in death, nor even in great inconvenience, even though the parasite is actually living at its expense. The presence of a few bots in the stomach of a horse may not affect that animal in the least, nor would the presence of a few lice on the body of an ox. But with the multiplication of these parasites there will be increased inconvenience to both hosts. The presence of a few maggots in the fleshy part of a sheep's tail might cause little damage, but let these be in the nasal sinuses or in the brain, then the gravity of the situation becomes greatly augmented. Thus the effect of parasitism on the host is dependent both on the *number* and *position* of the parasite.

Effect of Parasitism on the Parasite. — All parasites are more or less specialized in the direction of their habits; *e.g.* fleas are laterally compressed, to effect ease of motion between hairs; lice are horizontally flattened, and are provided with strong clasping organs by means of which they hold fast to hairs; both of these examples are wingless and have sacrificed much of the ordinary means of locomotion. Entoparasites are usually provided with specialized hooks, barbs, suckers, etc., for purposes of attachment to the alimentary canal or other organs, *e.g.* the botfly larvæ, and among the Helminthes, the flukes (Trematoda), the tapeworms (Cestoda), etc. Perhaps, because of the ease with which food is secured, the sense organs are usually not strongly developed; the eyes may be very simple or wanting. The mouth parts differ in the several groups, depending on the special habits of the insect. It is interesting to note that the parasitic habit has resulted in the development of structural similarity. This is particularly apparent in the clasping structures of the biting and sucking lice, which belong systematically to two different orders; namely, the Mallophaga and the Hemiptera, respectively.

Origin of Parasitism. — Modern parasites are restricted more or less completely to particular host animals, which necessitates the deduction that the parasite must have developed its habit after the existence of the host, and in consequence parasitism must be a recently acquired habit on the part of a one-time free-living organism. This becomes more apparent by a study of the life history of the parasite; invariably the earlier stages point to a primitively free-living existence. Perhaps the ancestors of a given group of modern parasites were attracted to the waste food, offal and exudations of certain animals; the search for food having become simplified, they began living as messmates, or commensalists, or as scavengers; the association between the two species became closer and eventually the line of parasitism was completed. This is also borne out by a study of the nearest allies of a given parasite, in which the gradation from the free-living animal to the parasite may be traced. The very close structural similarity between the free-living, wingless book louse, *Troctes divinatoria* Mull. (a member of the order Corrodentia, family Psocidæ) and a common hen louse, *Menopon biseriatum* Piaget (a member of the order Mallophaga), leads us to believe that the parasitic Mallophaga have been derived directly from the Psocidæ. Knowing the habits of the book louse, we can easily imagine how the line of parasitism might eventually have become established; *i.e.* from the eating of feathers, skins and excretions *off* the animal to the eating of the same *on* the animal as a host is not difficult to imagine at least.

Degrees of parasitism may also be illustrated by examples from the biting lice (Mallophaga, in which there are species having the power to run freely and live for a considerable length of time off the host, *e.g.* *Menopon pallidum* Nitzsch., the common hen louse, while other related species have become quite sessile, as in the extreme case of the worm-like louse (*Menopon titan* Piaget), inhabiting the gular pouch of the pelican. Among the fleas there are also good examples of gradation in habit and structure, *e.g.* the human flea (*Pulex irritans* Linn.), which has developed remarkable springing power and is comparatively free to move from place to place, while the mature female hen flea (*Echidnophaga gallinacea* Westw.) is usually quite sessile, holding fast to one point much like a tick.

Systematic Position of Animal Parasites. — Though parasitic animal organisms are found in other phyla, those affecting man and beast are included almost exclusively in the following:

a. *Protozoa,* — unicellular animals (Fig. 1); *e.g.* *Entamœba histolytica* Schaudinn, causing amœbic dysentery; *Plasmodium vivax* Grassi and Feletti, causing malaria; *Trypanosoma gambiense* Dutton, causing African sleeping sickness.

b. *Nemathelminthes,* — bilateral, unsegmented worms of cylindrical form (Fig. 2); *e.g.* *Trichinella spiralis* Owen, causing trichinosis; *Ascaris lumbricoides*, roundworm of man; *Ankylostoma duodenale* Dubini, a hookworm of man. Development is us ually direct.

c. *Platyhelminthes,* — bilateral worms; flattened dorsoventrally; no anal opening. Usually requiring an intermediate host.

1. *Cestoda,* — head or scolex with separable segments called proglottides (Fig. 3); *e.g. Tænia solium* Linn., the pork tapeworm of man; *Tænia saginata* Goeze, the beef tapeworm of man; *Dipylidium caninum* Linn., a common tapeworm of the dog.

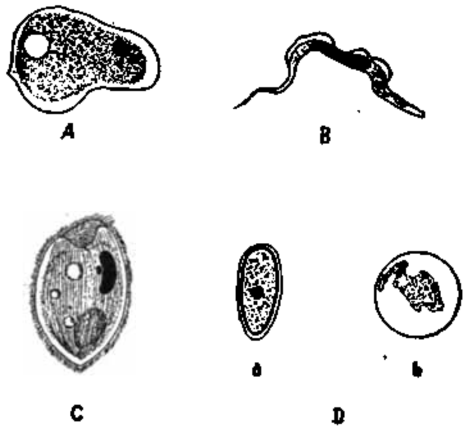

FIG. 1. — Types of Protozoa. A. Sarcodina, represented by *Entamœba histolytica* of Tropical Dysentery; B. Mastigophora, represented by *Trypanosoma gambiense* of African Sleeping Sickness; C. Infusoria, represented by *Balantidium coli*, causative organism of a certain oriental dysentery (redrawn after Leuckart); D. Sporozoa, represented by (*a*) *Coccidium oviforme* from liver of rabbit, (*b*) *Plasmodium vivax* of Malaria shown in a red blood corpuscle. (All greatly enlarged.)

FIG. 2. — Examples of parasitic round worms (Phylum Nemathelminthes, Class Nematoda). *a.* Round worm of swine (*Ascaris suum*) × .3; *b. Trichinella spiralis* (after Leuckart), greatly enlarged; *c.* Hookworm of man (*Ankylostoma duodenale*) × 1.25.

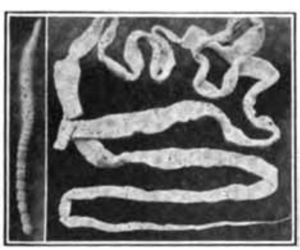

FIG. 3. — Examples of parasitic flat worms (Phylum Platyhelminthes, Class Cestoda. A poultry tape worm (*Drepanidotænia infundibuliformis* × 1) on the left; and a common tape worm of cattle (*Tænia expansa*, greatly reduced) on the right.

FIG. 4. — Example of parasitic flat worms (Phylum Platyhelminthes, Class Trematoda). A liver fluke of cattle (*Distomum americanum*) × 1.

2. *Trematoda,* — alimentary canal branched; mouth in a sucker; *e.g. Fasciola hepatica* Linn., the sheep liver fluke (Fig. 4).

d. Annelida, — bilaterally symmetrical, segmented or annulated worms.

1. *Chætopoda,* — locomotor chætæ; segmentation extending to internal organs, *e.g. Lumbricus terrestris* Linn., a common earthworm (non-parasitic) (Fig. 5).

FIG. 5. — Example of segmented cylindrical worms (Phylum Annelida, Class Chætopoda). Earthworm (*Lumbricus sp.*, × .5) non-parasitic, but may serve as an intermediary host for certain poultry tapeworms.

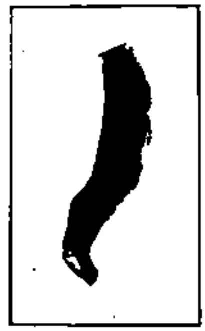

FIG. 6. — Example of segmented cylindrical worms (Phylum Annelida, Class Hirudinea). Leech (*Hirudo medicinalis*) × .5.

2. *Hirudinea,* — flattened; sucker at each end of body; arrangement of internal organs does not correspond to external segmentation; *e.g. Hirudo medicinalis* Linn., the medicinal leech (Fig. 6).

e. Arthropoda, — segmented body with jointed appendages; exoskeleton; bilateral symmetry; ventral nerve-cord;

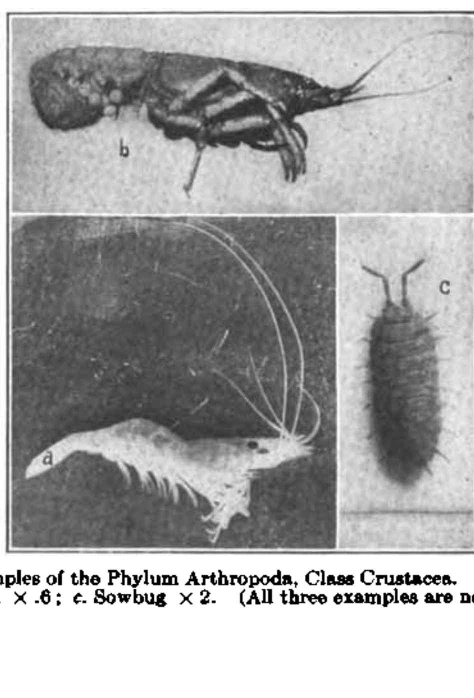

FIG. 7. — Examples of the Phylum Arthropoda, Class Crustacea. *a.* Shrimp × 1.2; *b.* Crayfish × .6; *c.* Sowbug × 2. (All three examples are non-parasitic.)

1. *Crustacea,* — aquatic; gill respiration; two pairs of antennæ; biramous appendages; *e.g.* the shrimp, the crayfish and the sow bug. (These examples are non-parasitic.) (Fig. 7.)

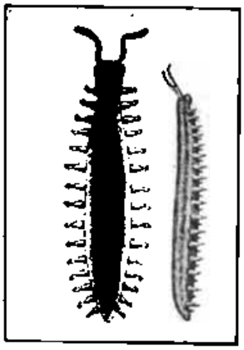

FIG. 8. — Example of the Phylum Arthropoda, Class Protracheata. Peripatus (after Folsom) × .5.

FIG. 9. — Examples of the Phylum Arthropoda, Class Myriapoda. *a.* A centipede × .5; *b.* A millipede × .7.

2. *Protracheata,* — elongate, wormlike, segmented body; paired, unsegmented appendages; one pair of antennæ; tracheal respiration; elongate dorsal heart; *e.g. Peripatus* (Fig. 8) (non-parasitic).
3. *Myriapoda,* — body elongate and wormlike; each segment except first two and last one bearing one pair of jointed walking appendages, *Centipedes,* some of which are venomous (Fig. 9*a*); or two pairs, *Millipedes* (Fig. 9*b*).

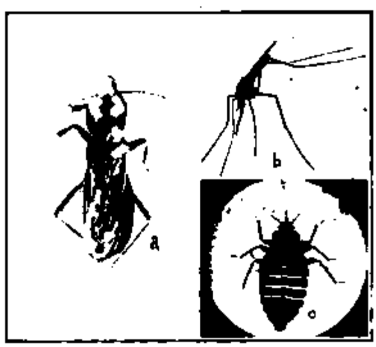

FIG. 10. — Examples of the Class Insecta. *a.* A Reduviid (cone nose) × 1; *b.* A mosquito (Anopheles) × 2; *c.* Bed bug (Cimex) × 2.5.

4. *Insecta,* — body divided into three divisions (head, thorax and abdomen); three pairs of walking appendages on thorax; two pairs of wings on thorax (may be reduced or absent); one pair of antennæ; compound eyes; usually three simple eyes; tracheated respiratory system; *e.g. Conorhinus protractus* Uhler (cone-nose); *Cimex lectularius* Linn. (bed-bug); *Anopheles maculipennis* Meig. (malaria mosquito); etc. (Fig. 10).

5. *Arachnida*, — head and thorax fused to form cephalothorax; four pairs of walking appendages on cephalothorax (larvæ may be hexapod); wingless; no antennæ; eyes simple, when present; *e.g. Latrodectes*

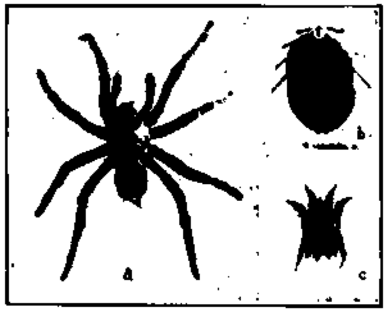

FIG. 11. — Examples of the Phylum Arthropoda, Class Arachnida. *a*. A spider × .5; *b*. A tick × 1.3; *c*. A mite × 30.

mactans Fabr., a poisonous spider; *Hadrurus hirsutus* Wood, scorpion; *Margaropus annulatus* Say, the Texas fever tick; *Dermanyssus gallinæ* Redi, the poultry mite; *Psoroptes communis* Furst, the scab mite. (Fig. 11).

CHAPTER III

INSECT ANATOMY AND CLASSIFICATION

The Insecta (Fig. 10) are essentially segmented animals, the primitive number of segments being probably nineteen or twenty, based on ontological evidence. This number is no longer evident, owing to the specialization of the head and posterior terminal segments. The most striking condition is the separation of the body into three divisions; the *head* bearing the antennæ, mouth parts and eyes; the *thorax* possessing the locomotor appendages, usually two pairs of wings and three pairs of legs; the *abdomen*, bearing no appendages except the terminal organs of sexual prehension in the male, or ovipositor in the female. The respiratory system of the insect consists of a complex series of tubes (Fig. 12) ramifying all parts of the body, carrying air from the outside through the spiracles segmentally arranged on both sides of the thorax and abdomen.

Fig. 12. — A few tracheal tubules taken from an insect. (Greatly enlarged.)

Insect Larvæ. — When insect larvæ, parasitic or accidental, are encountered in the body of man or beast, there may be some difficulty in classifying them readily, with the result that they may be incorrectly placed among the worms, for example, bots and warbles (Œstridæ), or screw worms (Chrysomyia) or other flesh fly larvæ in cases of intestinal myiasis. Usually these larvæ (Fig. 13) are short and plump, ordinarily possessing eleven or twelve well-marked segments. Furthermore, microscopic examination will reveal a system of minute tubules (Fig. 12), the tracheal breathing system, ramifying all internal parts of the body, even the minutest portions between muscle fibers. This system is not present in worms.

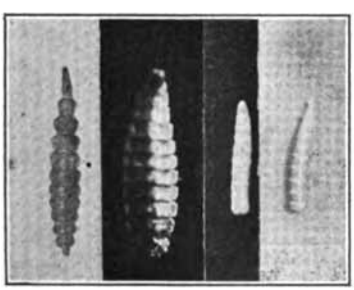

Fig. 13. — Insect larvæ, — showing typical external segmentation. ×1.

The larvæ of Dipterous insects (flies) are commonly called "maggots" and are footless; the larvæ of Coleoptera (beetles) are called "grubs," and have three pairs of feeble legs; the larvæ of Lepidoptera (moths and butterflies) have never less than four pairs of legs including prolegs and are known as "caterpillars"; Neuropterous larvæ (dobson flies, etc.) are not easily distinguished, but the presence of three pairs of legs with more than twelve body segments, including the head, will serve to distinguish these in at least many cases.

Importance of Knowing Internal Anatomy. — It is important that the student familiarize himself with the internal anatomy of the insect, with special reference to the digestive system and its accessory structures, such as the salivary glands. Two cases will point out this necessity:

1st. The simplest condition in which the internal organs of insects are concerned in disease transmission is in the case of the house fly, in which pathogenic organisms are sucked up with dejecta and are passed out with the feces of the fly, and deposited on human food, either in their original virulent condition or more or less attenuated or weakened.

2d. The more complicated condition is in the case of the Anopheles mosquito, which sucks up pathogenic organisms (malaria parasites) with the human blood, and these undergo very important and vital sexual changes within the body of the insect, eventually finding lodgment in the salivary glands of the same before introduction by the "bite" into the next human victim, — thus the insect is an essential intermediary host.

Digestive System. — There are three distinct regions to the insect intestine (Fig. 14); namely, (1) the *fore-gut*, consisting of the mouth, pharynx, esophagus and proventriculus; (2) the *mid-gut*, consisting of the stomach; and (3) the *hind-gut*, consisting of the ileum, colon,

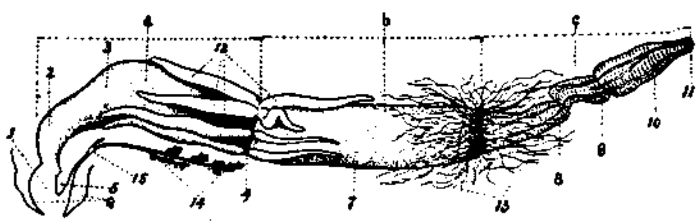

FIG. 14. — Drawing of a typical insectan alimentary tract. *a.* fore-gut; *b.* mid-gut; *c.* hind-gut; 1. pharynx; 2. œsophagus; 3. crop; 4. gizzard; 5. hypopharynx; 6. mandibles; 7. stomach; 8. ileum; 9. colon; 10. rectum; 11. anus; 12. gastric cæca; 13. Malpighian (excretory) tubules; 14. salivary gland; 15. salivary duct. × 2. (Adapted after Folsom.)

rectum and anus. The proventriculus presents merely a widened portion of the esophagus in the more generalized forms and serves as a food receptacle. In the more specialized groups, such as the Diptera and Lepidoptera, the crop is expanded into a capacious pocket or pouch. In such forms in which the *gizzard* is present this organ consists of a highly muscular dilation provided internally with chitinous teeth for grinding food; for example, the grasshopper. The stomach is a simple sac into which open the *gastric cæca*, generally few in number, which give rise to certain digestive fluids. At both ends of the stomach are located valves which direct the flow of the food. There is much variation in the length and degree of convolution of the hind intestine, but usually the three regions mentioned, namely, ileum, colon and rectum, may be located. Emptying into the ileum are the excretory or *Malpighian tubules* varying in number and length in the various groups of insects.

The salivary system consists of a pair of salivary glands (Fig. 15) which may be lobed, situated within the head, often extending into the thorax. Usually each gland empties into a *salivary duct*, the two ducts joining into a common duct which opens into the esophagus or pharynx. In many species of insects there is present a pair of *salivary reservoirs;* these may be located near the opening of the common duct and then present a compound condition, or may be situated on either side of the esophagus at the end of a long slender duct.

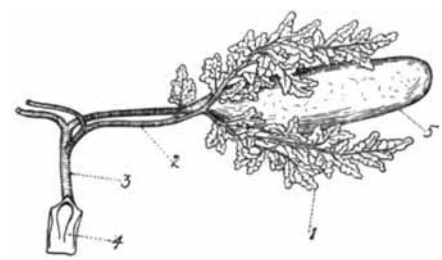

FIG. 15. — Salivary system (right side) of an insect, — a cockroach. 1. Salivary glands; 2. Salivary duct; 3. Common salivary duct; 4. Hypopharynx; 5. Reservoir. (Adapted after Miall and Denny.)

Insect Classification. — The Medical Entomologist must be equipped with a good knowledge of the basic principles of classification, so as to be able to correctly place the insect at hand in its proper order and family at least, and in the case of parasitic insects should be able to run the specimen to the species with the aid of a key. To determine the *Order* to which an insect belongs one need usually only know the character and structure of the wings when present and the type of the mouth parts. This will enable the student to place at least ninety per cent of the commoner insects in their proper *Orders*. Unfortunately the parasitic forms have undergone many changes such as reduction or loss of the wings and great modification in form, but generally the mouth parts will serve as a ready means for rough identification. Before passing on to a list of the Orders of insects, the usual basis for classification will be considered here, viz.: —

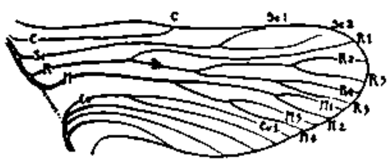

FIG. 16. — Hypothetical type of wing venation. *A.* anal vein; *C.* costa; *Cu.* cubitus; *M.* media; *R.* radius; *Sc.* subcosta. (Redrawn from Folsom, after Comstock and Needham.)

1. Wings, — (*a*) presence or absence of, (*b*) form, (*c*) structure.
2. Mouth parts, — (*a*) biting (mandibulate), (*b*) sucking (haustellate).
3. Metamorphosis, — (*a*) primitive, (*b*) simple (incomplete), (*c*) complex (complete).

Wings. — The earliest systems of insect classification were based on wing characters, which together with the mouth parts offer a basis for the more modern arrangement also. The venation of insect wings is so markedly characteristic for each species that even a part of a wing is

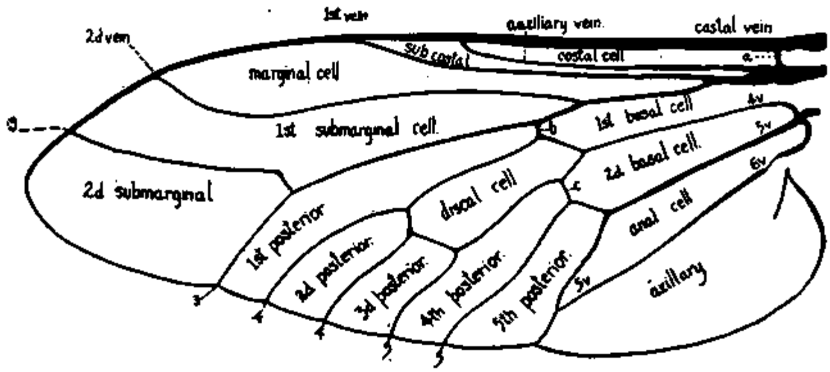

FIG. 17. — Wing of an insect (Tabanus), to illustrate terminology as applied to venation and cells.

often all that is necessary for determination. There are typically two pairs of wings present, situated on the mesothorax and metathorax, though in many parasitic insects, such as the bedbugs, lice, fleas, certain louse flies, etc., the wings are absent. Wingless insects such as those mentioned should not be included with the *Aptera*, which is an order of *primitively* wingless insects. The parasitic wingless insects fall under several different orders, as will be seen. To avert confusion it is therefore probably better to dispense with the term *Aptera* and substitute the term *Thysanura* as used by a number of entomologists.

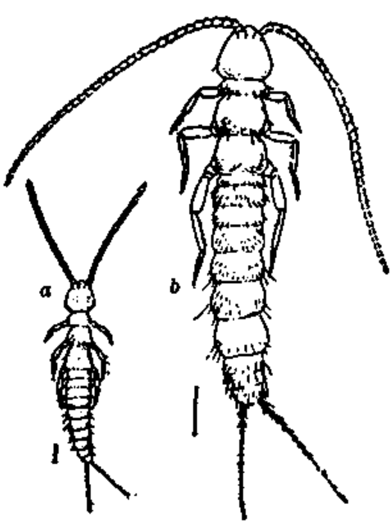

FIG. 18. — Illustrating primitive metamorphosis. *a*. young of a Thysanuran insect (Campodea); *b*. adult of the same. (After Kellogg.)

In form the wing presents a more or less triangular appearance. Generally the fore and hind wings differ considerably in size; the fore wing in some groups, such as the May flies, many butterflies and moths, and the bees and wasps, is larger than the hind wing, while in the grasshoppers, cockroaches, beetles, etc., the fore wing is narrow and serves largely as a cover (elytron) to the hind wing, which folds fanlike. Again, in the dragon flies, white ants and ant lions, the fore and hind wings are nearly equal. In the flies, the hind pair of wings is replaced by club-shaped organs known as *halteres*, leaving consequently only one pair of wings, hence the name Diptera (two-winged).

There is also a great variation in structure of the wings, though for each order a certain general condition prevails; *e.g.* the Neuroptera have thin membranous wings, often quite filmy; however, Diptera and many Hemiptera have the same texture, but possessing fewer wing veins and a different venation. The Diptera can, of course, be readily distinguished by the presence of but a single pair of wings. The typical Hemiptera have the front wings thickened at the base, while the apical portion is membranous (Hemiptera-Heteroptera). The other two divisions of this order, one of which has a pair of entirely membranous wings (Hemiptera-Homoptera), the other wingless (Hemiptera-Parasita), can be readily distinguished on the basis of mouth parts.

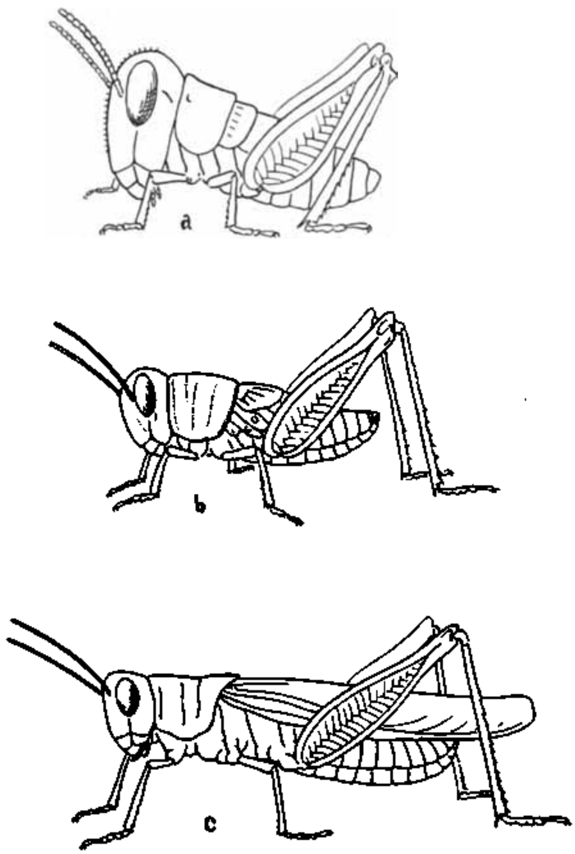

FIG. 19. — Illustrating simple metamorphosis. *a*. Young wingless grasshopper; *b*. Showing wing pads after the first molt; *c*. Adult of the same. (Redrawn after Packard.)

The venation of the insect wing, as has been mentioned, is an important factor in classification on account of the great variety of arrangement, and the reliability of this character for identification of the family and species. By a careful study of the evidence, a fundamental type of wing venation has been constructed by Comstock and Needham. The figure (Fig. 16) illustrating this type will be useful in determining the identity of the principal veins. The spaces between the veins are called *cells*, shown in Fig. 17, which figure also illustrates the use of the numerical system of nomenclature.

Metamorphosis. — In order to attain to the size and development of the parent the young insect undergoes greater or less change in size, form and structure, which series of changes is termed *metamorphosis*. The least change is found in the Thysanura (Aptera), which are primitively wingless, and hence the newly emerged young individual is externally unlike the parent only in size, — this type of metamorphosis is termed *primitive* (Fig. 18).

A greater difference is found in the young and adult grasshopper (Fig. 19). Other than the difference in size and sexual maturity the absence of wings in the young is at once apparent. In order to reach the winged condition, the young individual molts at intervals, and with each molt secures longer wings until after a definite number of molts the fully developed wings are present. The following stages may be recognized: (1) *egg*, (2) *nymph*, (3) *imago* (not sexually mature) and (4) *adult* or sexually mature individual. This type of metamorphosis is termed *simple* or *incomplete*.

The greatest difference between the newly hatched young and the parent occurs in such forms as the house fly (Fig. 20), the butterfly,

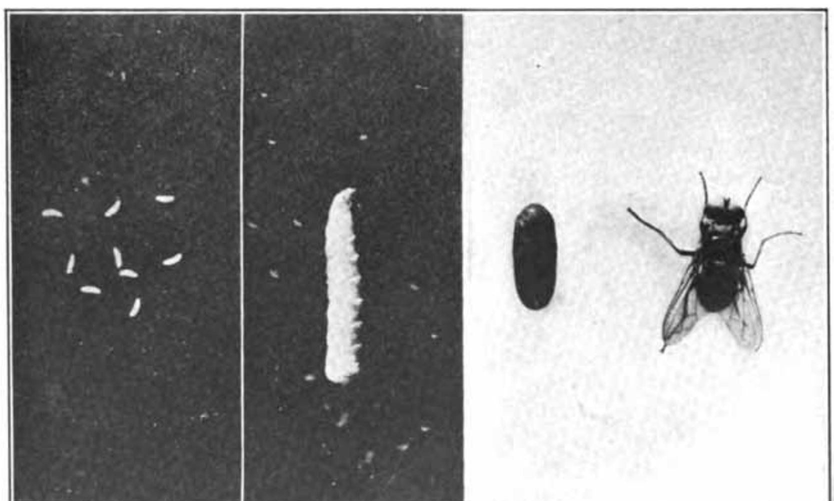

FIG. 20. — Illustrating complex metamorphosis. Life history of the common housefly. *a.* egg; *b.* larva; *c.* pupa; *d.* adult.

etc. In these forms the newly emerged young individual has no resemblance whatever to the adult, having the appearance of a segmented worm. (Of course, the internal anatomy and certain other features are distinctly insectan.) The fact that the young are mandibulate and the adults haustellate in Diptera and Lepidoptera offers much interesting ground for ecological discussion, but is out of order at this time. In order to attain the winged condition of the adult from the wingless, wormlike condition of the young, many profound changes must be undergone and a new stage is entered, the *pupa*, or resting stage, in which this transformation is accomplished. The newly emerged young insect is called the *larva*, and we have consequently the following stages to deal with: (1) *egg*, (2) *larva*, (3) *pupa*, (4) *imago*, (5) *adult*. This type is termed *complex* or *complete* metamorphosis.

External Anatomy. — In order to familarize himself with the external anatomy of insects, especially with the parts upon which classification is mainly based, the student should study carefully some hard-bodied insect of a generalized nature. Such an insect need not be a parasite, indeed, the author prefers that a non-parasitic form be used because there is less specialization. The common grasshopper answers the purpose very well, and a careful study of Fig. 21 is recommended.

Keys to Classification. — The student is now prepared to better understand the use of a key to classify any insect at hand. The first thing he needs to do is to place the insect in its proper order, which may be done with the aid of the following key. While the use of a key in classification of animals may seem to be essential, the student should not become a slave to this very mechanical method of placing creatures in their proper class, order or family.

Key to the Orders of Insects [1]

A. *Primitive wingless insects; mouth parts well developed, but all except the apices of the mandibles and maxillæ withdrawn into a cavity in the head;* tarsi (feet) always one or two clawed; body sometimes centipede-like, with well-developed abdominal legs, in this case tarsi two-clawed — (the simplest insects) . . . . APTERA

AA. Normally *winged* insects, wings sometimes rudimentary or absent; mouth parts not withdrawn into a cavity in the head.

B. *Mouth parts, when developed, with both mandibles and maxillæ fitted for biting; abdomen broadly joined to thorax; tarsi never bladder-shaped;* when mouth parts are rudimentary, if the wings are two, there are no halteres; if the wings are four or absent, the body is not *densely* clothed with scales.

C. *Posterior end of abdomen with a pair of prominent unjointed forceps-like appendages; fore wings, when present, short veinless, horny or leathery* — (Earwigs) . . EUPLEXOPTERA

CC. *Posterior end of abdomen usually without prominent unjointed forceps-like appendages;* when these are present the fore wings are always developed, *veined*.

D. *Fore wings, when present, veined and membranous, parchment-like or leathery*, when absent, the labium (underlip) either cleft in the middle, or the mouth parts prolonged into a distinct beak.

E. *Fore wings, when present, thicker than hind wings, somewhat leathery or parchment-like; hind wings folded several times, lengthwise, like a fan, in repose;* when wings are absent, prothorax large — (locusts, crickets, cockroaches, etc.) ORTHOPTERA

[1] After Kellogg (by permission) arranged by Professor H. E. Summers.

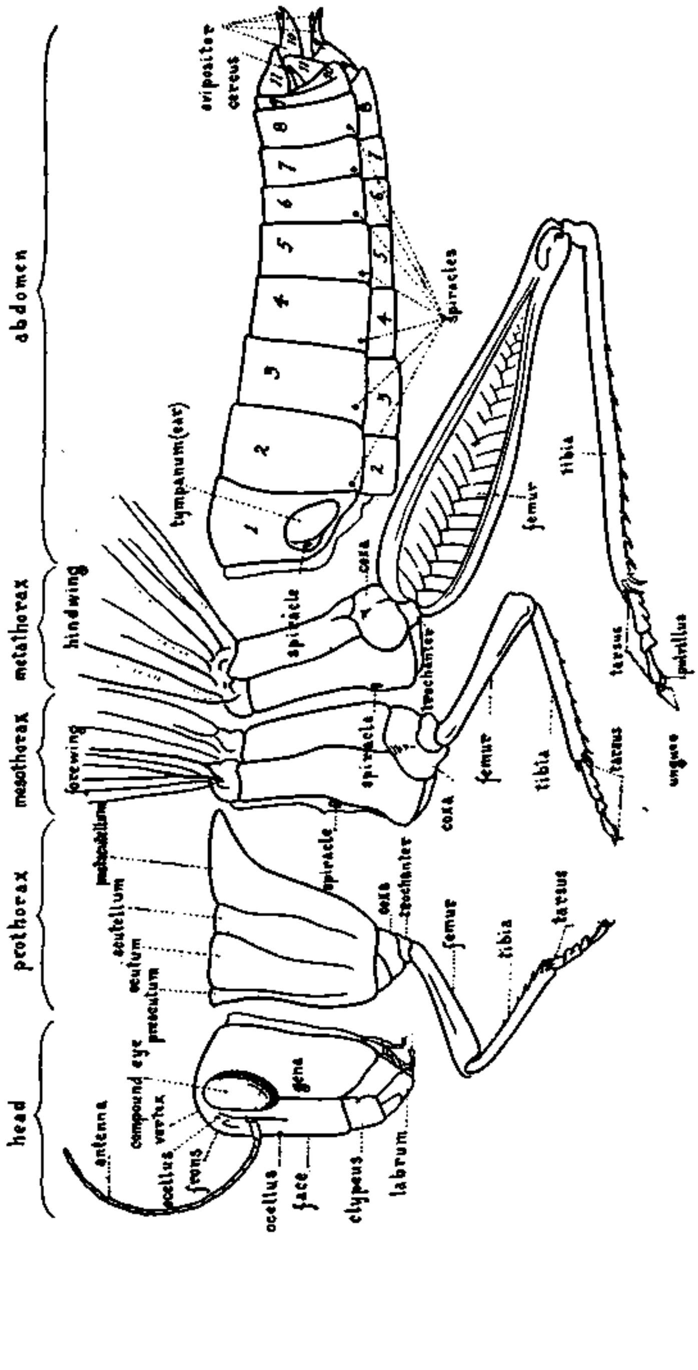

FIG. 21. — External anatomy of an insect (grasshopper), showing many of the parts commonly referred to in the classification of insects in general.

EE. *Fore wings membranous, of same structure as hind wings; hind wings usually not folded; but occasionally folded like a fan;* when wings are absent, prothorax small.

F. *Antennæ inconspicuous.*

G. *Hind wings smaller than fore or absent; posterior end of abdomen with two or three many-jointed filaments* — (May flies) . . . . . EPHEMERIDA

GG. *Hind wings not smaller than fore; posterior end of abdomen without many-jointed filaments* — (dragon flies and damsel flies) . . . . ODONATA

FF. *Antennæ conspicuous.*

G. *Tarsi less than five-jointed; labium cleft in the middle.*

H. *Wings always present, although sometimes very small; hind wings broader than fore wings, folded in repose; prothorax large,* nearly flat on dorsal surface — (Stone flies) . . . PLECOPTERA

HH. *Hind wings, when present, not broader than fore wings, not folded in repose, prothorax small, collar-like.*

I. *Tarsi four-jointed, wings when present equal in size* — (Termites) . . . ISOPTERA

II. *Tarsi one to three jointed.*

J. *Tarsi one or two jointed always wingless* — (biting lice) MALLOPHAGA

JJ. *Tarsi usually three-jointed; occasionally two-jointed, in which case wings always present, fore wings larger than hind wings* — (Book lice, etc.) CORRODENTIA

GG. *Tarsi five-jointed, but with one joint sometimes difficult to distinguish; labium usually entire in middle, sometimes slightly emarginate.*

H. *Wings, when present, naked or slightly hairy; hind wings with or without folded anal space; in former case prothorax large and nearly flat on dorsal surface; in wingless forms* mouth prolonged into a distinct beak.

I. *Mouth parts not prolonged into a distinct beak, at most slightly conical* — (Dobsons, ant lions, etc.) NEUROPTERA

II. Mouth parts prolonged into a distinct beak — (Scorpion flies, etc.) . . MECOPTERA

HH. Wings, when present, thickly covered with hairs; hind wings usually with folded anal space; prothorax small, collar-like; mouth not prolonged into a beak — (Caddis flies) . . . TRICHOPTERA

DD. Fore wings, when present, veinless; horny or leathery; when absent, labium entire, and mouth parts not prolonged into a distinct beak — (Beetles) COLEOPTERA

BB. Mouth parts, when developed, more or less fitted for sucking; sometimes also fitted in part (the mandibles) *for biting; in this case either* (1) *base of abdomen usually strongly constricted, joined to thorax by a narrow peduncle, or* (2) *the tarsi bladder-shaped, without claws;* when mouth is rudimentary either the wings are two and halteres are present, or the wings are four or none and the body (and wings if present) are densely clothed with scales.

C. Prothorax free; body (and wings if present) never densely clothed with scales; maxillary palpi usually absent; when present, tarsi bladder-shaped, without claws.

D. Tarsi bladder-shaped, without claws; wings four (sometimes absent), narrow, fringed with long hairs; maxillæ triangular, with palpi — (Thrips) . THYSANOPTERA

DD. Tarsi not bladder-shaped, usually clawed; wings not fringed with long hairs; maxilla (when mouth is developed) bristle-like, without palpi — (Bugs) . . . HEMIPTERA

CC. Prothorax not free; maxillary palpi present, sometimes rudimentary and difficult to see, in which case body (and wings if present) densely clothed with scales; tarsi never bladder-shaped, usually clawed.

D. Mandibles often rudimentary, when present bristle-like.

E. Wings four (sometimes wanting), clothed with scales; body covered thickly with scales or hairs; mouth, when developed, a slender, sucking proboscis, closely coiled under head — (Moths and butterflies) LEPIDOPTERA

EE. Wings two (or wanting), naked or with scattered hairs; hind wing in winged forms represented by halteres; body either naked or with scattering hairs; mouth, a soft or horny beak not coiled under head.

F. Prothorax poorly developed, scarcely visible from dorsalside — (Flies) . . . . DIPTERA

FF. Prothorax well developed, distinctly visible from dorsal side; wings never present (Fleas) SIPHONAPTERA

DD. Mandibles well developed, fitted for biting; wings four (sometimes two or none), naked or with scattered hairs — (Ichneumon flies, gallflies, wasps, bees and ants) HYMENOPTERA

CHAPTER IV

INSECT MOUTH PARTS

Importance of Mouth Parts. — It is evident that an insect possessing mouth parts capable of penetrating the skin of the higher animals must be looked upon as a possible carrier of blood infection, although it may,

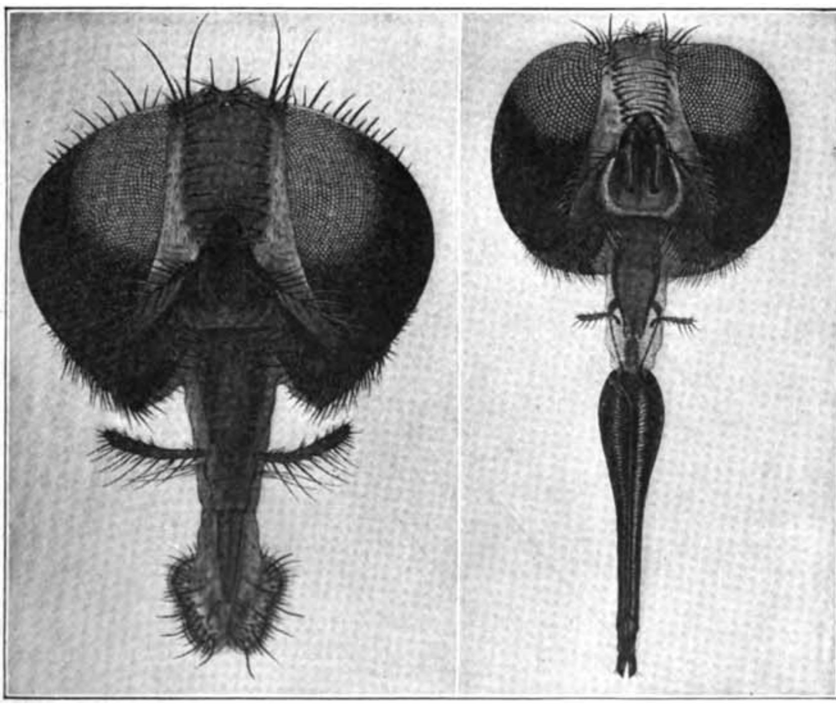

FIG. 22. — Head and proboscis of the common house fly (*Musca domestica*) on the left; the stable fly (*Stomoxys calcitrans*) on the right. Though closely related systematically, the mouth parts of the two species are very different; both are suctorial, but the former cannot pierce the skin while the proboscis of the latter encloses piercing setæ adapted for that purpose.

in actual experience, never attack such animals. If the insect is provided with mouth parts of the usual biting type or is non-piercing, it cannot relate to the transmission of infection introduced into the circulation, except through a previously inflicted open wound.

The mosquito would be harmless as far as malaria and yellow fever are concerned if the mouth parts were of the mandibulate or biting type. These insects together with certain other species such as the stable fly (*Stomoxys calcitrans*), the tsetse flies and the ticks are important because of the power which they possess of piercing the skin of higher animals and thus introducing pathogenic organisms into the blood.

The actual measures of control are often dependent on a knowledge of the mouth parts of the insect concerned.

Classification of Mouth Parts. — From the standpoint of Medical Entomology it is not serviceable to divide insects into only two general groups based on the mouth parts, *i.e., mandibulata* (biting) and *haustellata* (sucking). This becomes evident when it is considered that the house fly (*Musca domestica*) and the stable fly (*Stomoxys calcitrans*) both have haustellate mouth parts (Fig. 22), belong to the same family (Muscidæ), and are, therefore, systematically closely related; yet from the standpoint of disease transmission differ widely. By virtue of the piercing stylets enclosed within the labium, the stable fly relates to direct infection (inoculation), while the proboscis of the house fly, quite ineffective as a piercing organ, relates it to indirect infection. Because of the deficiencies of the older systems of mouth-part classification the following types will be recognized.

1. *Orthopteron type,* — generalized mouth parts consisting of opposable jaws used in biting and chewing, as in the grasshopper.
2. *Physopodan type,* — mouth parts representing an intermediate type; approaching the biting form, but functioning as suctorial organs, as in the thrips.
3. *Hemipteron type,* — mouth parts consisting of piercing suctorial organs, comprising three or four stylets closely ensheathed within the labium, as in the cone-nose and bedbug.
4. *Dipteron type,* — suctorial organs, piercing or non-piercing; no special representative is available for the entire group of Diptera, hence the following subtypes must be recognized.
   - *a.* First subtype, — mosquito; mouth parts consisting of six piercing stylets, loosely ensheathed within the labium.
   - *b.* Second subtype, — horsefly; mouth parts consisting of six short bladelike structures used for piercing and cutting, all loosely ensheathed within the labium.
   - *c.* Third subtype, — stable fly; mouth parts consisting of two heavy, piercing stylets, closely ensheathed within the labium.
   - *d.* Fourth subtype, — house fly; mouth parts consisting of a muscular proboscis, not suited for piercing; stylets aborted.
5. *Hymenopteron type,* — mouth parts consisting of suctorial, lapping organs, mandibles specialized for portage and combat, as in the bee, wasp and ant.
6. *Lepidopteron type,* — mouth parts consisting of a suctorial coiled tube, as in the cabbage butterfly.

Morphology of Mouth Parts

The Orthopteron Type. — To illustrate this type either the grasshopper or the cockroach may be used, but since the former is more easily obtainable and can be handled more satisfactorily, it will serve this purpose well. This type, the mandibulate or biting, is the generalized or primitive form and will serve as a basis for later comparisons and derivations. It is not of direct importance in relation to Medical Entomology except as it furnishes a basis for a better understanding of the haustellate or sucking type.

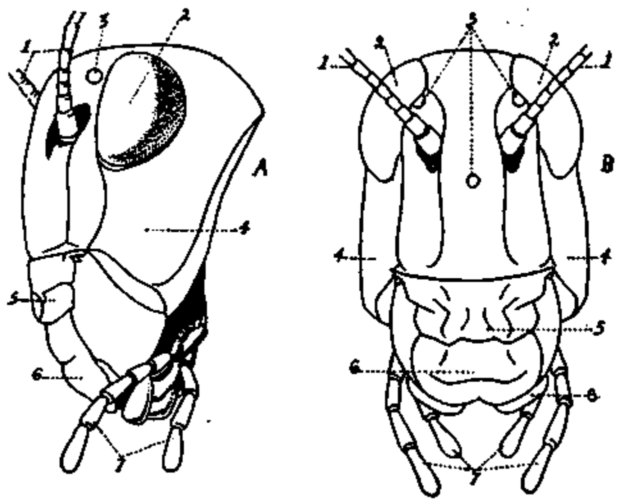

Fig. 23. — Head of a grasshopper, to illustrate the relative position of head structures in insects. A. side view; B. front view. 1. antennæ; 2. compound eye; 3. ocelli (simple eyes); 4. gena (cheek); 5. clypeus; 6. labrum; 7. palpi; 8. labium. (Redrawn after Folsom.)

If the head of the grasshopper (Fig. 23) is viewed from the side and again from the front, the relative position of the parts will be better understood. Separating the mouth parts (Fig. 24) of the grasshopper, the following structures will be observed. In front, low down on the head, hangs the labrum or upper lip, easily lifted as one would raise a hinged lid, the hinge line being at the lower part of the sclerite or plate, known as the *clypeus*.

The labium functions as does the upper lip in higher animals, *i.e.*, it draws the food toward the mandibles. In this the labrum is greatly aided by a rough structure called the *epipharynx*, which forms the inner lining of the labrum and clypeus. Because of the close association of these two structures they are often referred to as a double organ, the *labrum-epipharynx*. Removing the labrum, a pair of heavy, black, opposable jaws, the *mandibles*, is exposed. These are biting structures *par excellence*. They are toothed and movable laterally, instead of vertically as in the vertebrates. Dislodging the mandibles brings into view the pair of maxillæ, or accessory jaws. These organs are known as *first maxillæ*. They are composite structures separable into *cardo, stipes, lacinia, galea* and *palpus*, which should be carefully observed, inasmuch as they undergo great modification in the remaining types of mouth parts. The two supporting sclerites of the maxillæ are called the *cardo* (basal) and *stipes* (the second), while the distal lobes are called (1) the maxillary *palpus* (a jointed structure), (2) the *galea* (median and fleshy), (3) the *lacinia* (inner and toothed, capable of aiding in comminuting food).

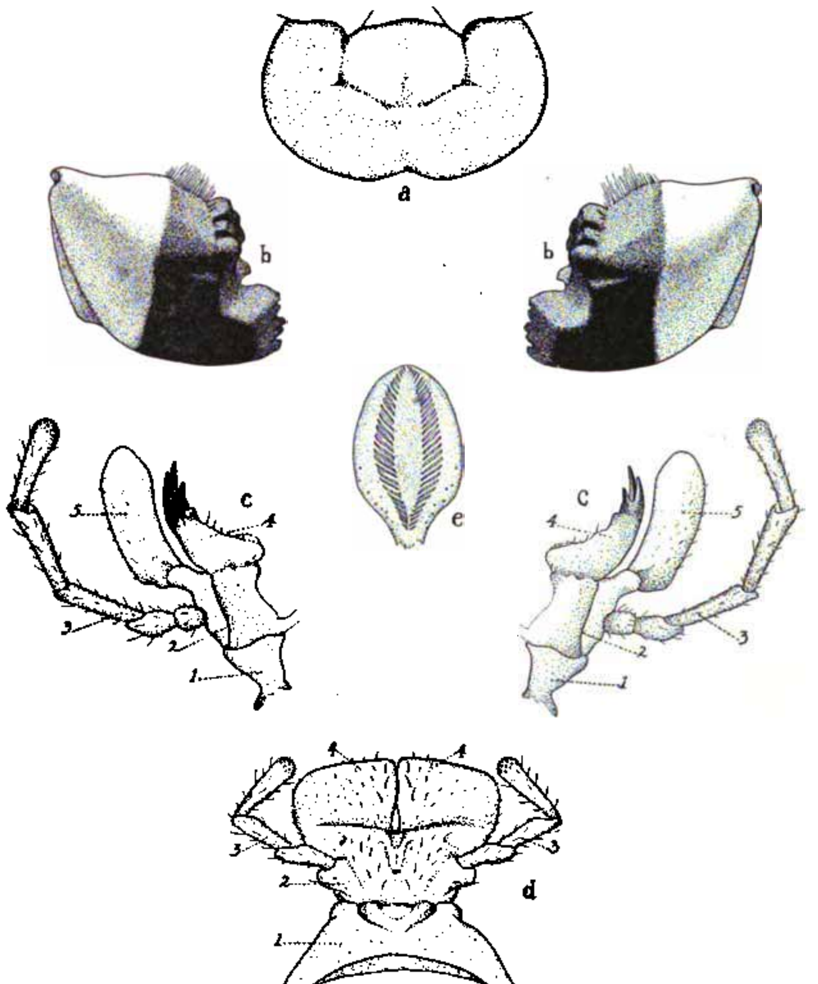

FIG. 24. — Mouth parts of a grasshopper, typical mandibulate structures, Orthopteron type. *a.* labrum; *b.* mandibles; *c.* maxilla, consisting of (1) cardo, (2) stipes, (3) palpus, (4) lacina, (5) galea; *d.* labium, consisting of (1) submentum, (2) mentum, (3) palpus, (4) ligula; *e.* hypopharynx or tongue.

Underneath the maxillæ and forming the floor of the mouth lies the lower lip or *labium*, a double structure frequently called the *second maxilla*. On the same plan as the maxillæ, the labium consists of a basal sclerite, the *submentum*, followed by the *mentum*, upon which rest the *labial palpi* (a pair of outer jointed structures to the right and left), and the *ligula* (a pair of strap-like plates which together correspond to the upper lip). The labium is also subject to much modification in insects.

The fleshy organ still remaining in the mouth cavity after the parts just described have been removed is the tongue or *hypopharynx*, an organ of taste, functionally comparable to the tongue of vertebrates.

The mandibles are most useful landmarks, since they are almost universally present in insects, though in various degrees of development from the strong mandibles of certain beetles (Lucanidæ) to the vestigial structures in certain Lepidoptera. In the Hymenoptera, even though the order is of the haustellate type, the mandibles are nevertheless important structures, serving, for example, in the honeybee as wax implements and organs of defense, and in ants as organs of portage and combat. In Hemiptera and Diptera the mandibles are modified into piercing organs. The maxillæ are subjected to great modification.

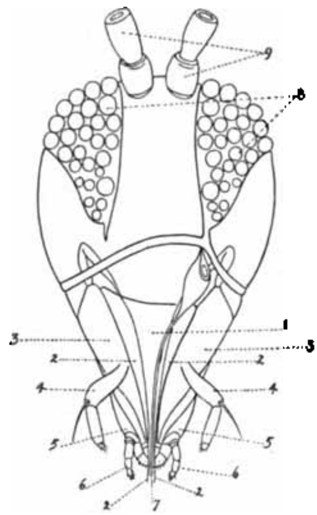

FIG. 25. — Head and mouth parts of thrips, mandibulate in structure but crudely suctorial in function. Physopodan type. Front view of head. (1) labrum, (2) mandibles, (3) maxillæ, (4) maxillary palpi, (5) labium, (6) labial palpi, (7) hypopharynx (?), (8) eyes, (9) antennæ. (Redrawn after Uzel.)

Physopodan Type. — Though like the first type, unimportant in its relation to disease transmission, this type, the Physopodan (Fig. 25), is distinctly important phylogenetically as a connecting link between the biting and piercing-sucking mouth parts. It is in the very minute thrips (*Physopoda*) that we find a transitional type of mouth parts, biting in general structure but sucking in function. The parts are all more or less readily traceable to the generalized Orthopteron type, but have become considerably elongated for piercing and are suctorial in function.

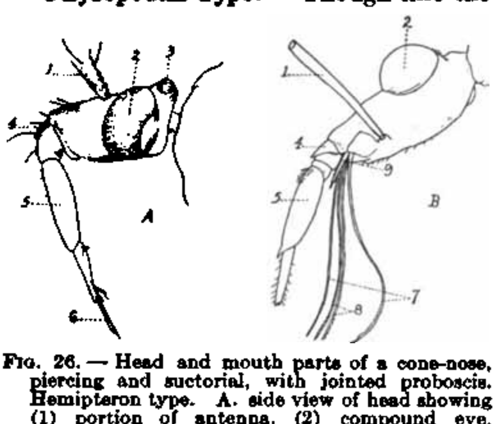

FIG. 26. — Head and mouth parts of a cone-nose, piercing and suctorial, with jointed proboscis. Hemipteron type. A. side view of head showing (1) portion of antenna, (2) compound eye, (3) ocellus, (4) clypeus, (5) jointed labium, (6) protruding setæ or piercing bristles, consisting of the mandibles and maxillæ. B. Shows setæ withdrawn from labium. (7) mandibles, (8) maxillæ, (9) hypopharynx.

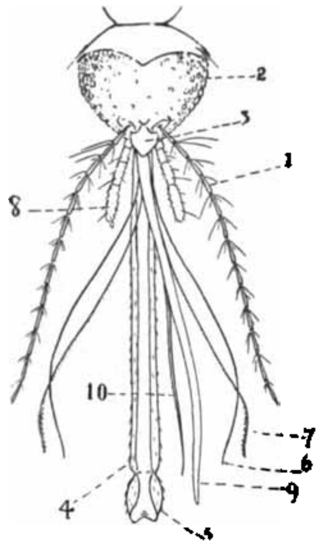

FIG. 27. — Head and mouth parts of a mosquito (*Culex sp.*). Illustrating the generalized Dipteron type of mouth parts (first subtype) with maximum number (six) of bristle-like stylets. (1) Nematoceran antennæ; (2) compound eyes; (3) clypeus; (4) labium; (5) labella; (6) mandibles; (7) maxilla; (8) maxillary palpi; (9) labrum; (10) hypopharynx.

Hemipteron Type. — A very different sort of organ than those above described is found in the Hemiptera (Fig. 26). Here the labium forms a prominent beak which is usually three (rarely one or four) jointed and telescopic. This beak incloses a pair of *mandibles*, often provided with terminal barbs, and a pair of maxillæ, all stylet-like and of great efficiency in piercing the skin. The maxillæ are more or less completely joined, forming a tube, so that only three stylets can be seen on examination. The *labrum* is quite short and inconspicuous.

Dipteron Type. — (*a*) *First Subtype, the Mosquito.* — The most generalized type of Dipteron mouth parts is found in the mosquito (Fig. 27), hence here we find the maximum number of stylets representing the structures of the more generalized type, loosely ensheathed within the elongated *labium*, the whole forming a prominent beak or proboscis. The identity of the six stylets is not well established, though it is generally accepted that they represent the two *mandibles*, the two *maxillæ* (distinctly serrated distally), the *hypopharynx*, and the *labrum-epipharynx*. The *palpi*

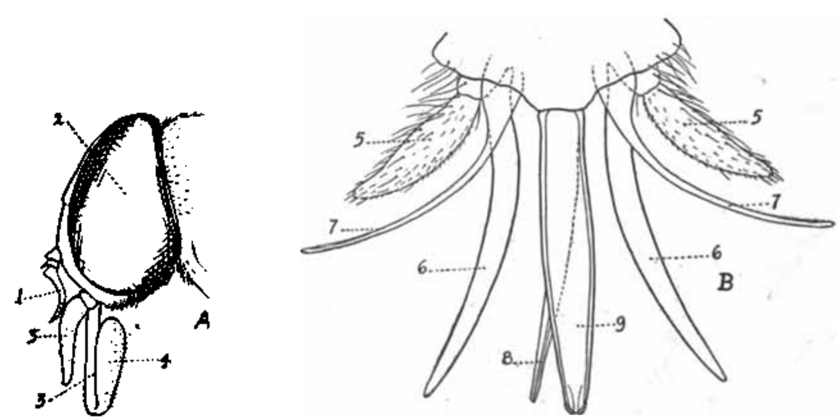

FIG. 28. — Head and mouth parts of a horsefly (*Tabanus*). The maximum number of parts is retained, but the piercing structures are distinctly blade-like. Dipteron type, second subtype. A. Side view of head showing (1) antenna (brachycerous), (2) compound eye, (3) labium, (4) labella, (5) maxillary palpus. B. Piercing structures exposed, labium removed. (6) mandibles, (7) maxillæ, (8) hypopharynx, (9) labrum-epipharynx.

are conspicuous structures in all mosquitoes and are useful as a means for identification. These represent the *maxillary palpi* of the grasshopper, while the pair of flattened lobe-like organs forming the distal portion of the proboscis are said to represent the *labial palpi* and are called the *labella.*

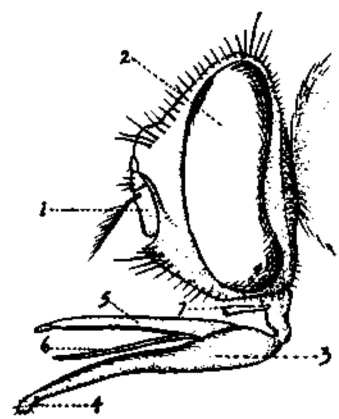

FIG. 29. — Head and mouth parts of the stable fly (*Stomoxys calcitrans*). Stylets reduced in number, closely ensheathed by the labium. Dipteron type, third subtype. Side view. (1) antenna, (2) compound eye, (3) labium, (4) labella, (5) labrum, (6) hypopharynx, (7) maxillary palpi.

(*b*) *Dipteron Type, Second Subtype, the Horsefly.* — While retaining the same number of parts as the mosquito, this subtype is distinctly characterized by its flattened blade-like condition (Fig. 28). That these mouth parts serve primarily as cutting structures is evident from the quantity of blood usually drawn by the "bite" of a horsefly, especially one of the larger species such as the black horsefly (*Tabanus atratus*). The *labium* is the conspicuous median portion loosely ensheathing the blades and terminating in large *labella.* The *mandibles* are distinctly flattened and saber-like, while the *maxillæ* are narrower and provided with conspicuous *palpi.* The *hypopharynx* and *labrum-epipharynx* are both lancet-like. In the male

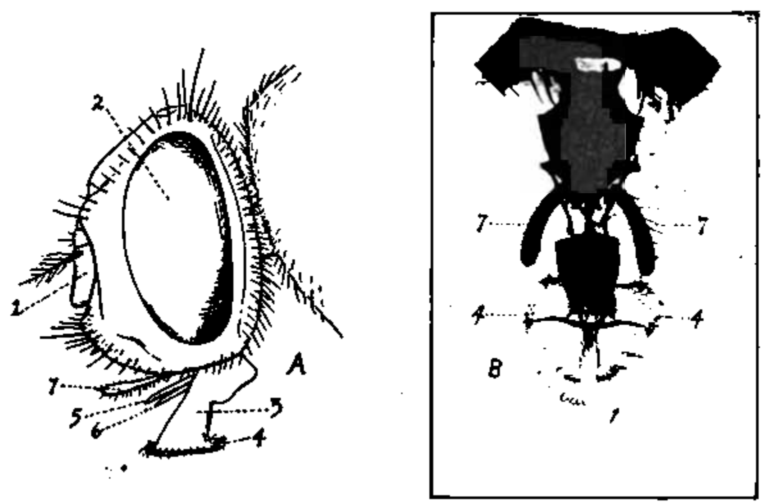

FIG. 30. — Head and mouth parts of the house fly (*Musca domestica*). Piercing stylet rudimentary. Muscular fleshy proboscis not suited for piercing the skin of higher animals. Dipteron type, fourth subtype. A. Side view. (1) Antenna, (2) compound eye, (3) labium, (4) labella, (5) labrum, (6) hypopharynx, (7) maxillary palpi; B. Front view of proboscis.

these piercing parts are very weakly developed and are not useful as weapons of attack.

(*c*) *Dipteron Type, Third Subtype, the Stable Fly.* — This subtype (Fig. 29) is represented by a group of flies in which the mouth parts are distinctly specialized for piercing, and show, together with the next subtype, to what extent these structures may become differentiated within the same family of insects.

The proboscis at rest is carried at the position of a bayonet at charge, and is therefore provided with a prominent muscular elbow or knee.

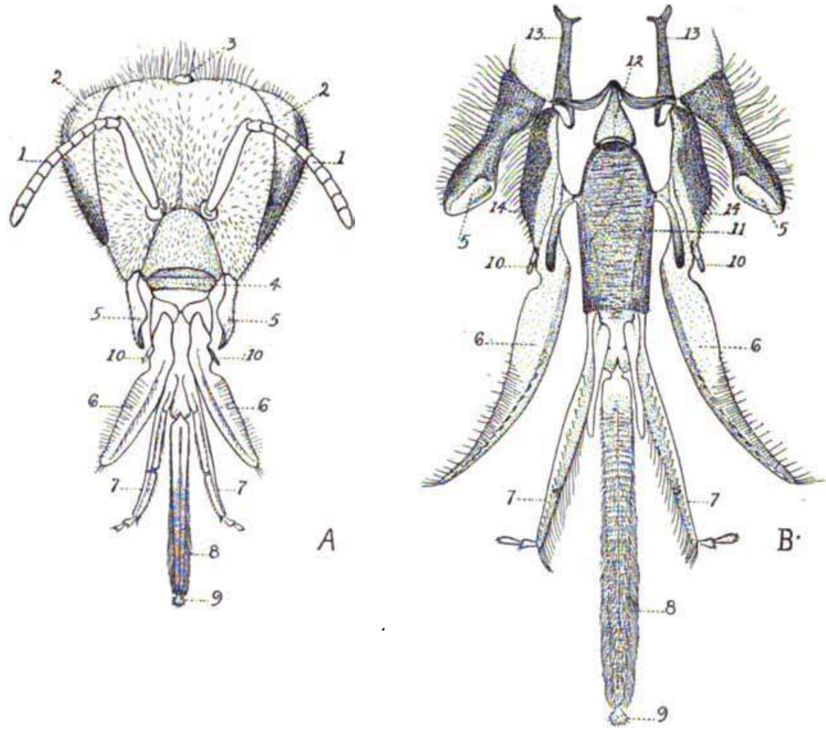

FIG. 31. — Head and mouth parts of the honeybee (*Apis mellifera*). Both types of mouth parts well developed but the mandibles are used chiefly for portage and modeling. (Hymenopteron type.) A. Front view of the head showing (1) antennæ, (2) compound eyes, (3) simple eye, (4) labrum, (5) mandibles, (6) maxillæ (lacinia), (7) labium (palpi only), (8) hypopharynx (?); B. Mouth parts removed to show the parts, (5) mandibles, (6) maxillæ (lacinia), (7) labium (palpi only), (8) hypopharynx (?), (9) bouton, (10) maxillary palpus, (11) mentum, (12) submentum, (13) cardo, (14) stipes.

This conspicuous organ (the proboscis) is the *labium* terminating in the *labella*, which are provided with a complex series of cutting and adhesive structures. Within the folds of the labium and easily removable through the upper groove lie two setæ, the *labrum*, the uppermost and heavier stylet, and the *hypopharynx*, a lower and weaker one, the two forming a sucking tube supported within the folds of the labium. The *maxillary palpi* are located at the proximal end of the proboscis.

(*d*) *Dipteron Type, Fourth Subtype, the House Fly.* — Here (Fig. 30) the prominent fleshy proboscis consists mainly of the labium, which terminates in a pair of corrugated rasping organs, the *labella,* and is attached in elbow-like form to the elongated head. The entire structure is highly muscular and may be either protruded in feeding or partially withdrawn while at rest. Lying on top of the grooved labium is the inconspicuous prolonged spade-like *labrum,* which forms, with the hypopharynx, a sucking tube, supported by the labium, which latter also incloses the salivary canal. By an examination of the labrum it will be seen that it forms a kind of convex covering to the concaved hypopharynx, thus giving rise to a food tube. The maxillæ have evidently become fused with the fleshy elbow of the proboscis and only the prominent *maxillary palpi* remain.

Hymenopteron Type. — In this type the two general classes of mouth structures, the *Mandibulate* and *Haustellate,* find a rather strong development in the same species, though the mandibles are not involved in the feeding process. The honeybee (Fig. 31) serves as a representative species. The *labrum* is narrow and quite simple, the *mandibles* are easily distinguishable and are useful wax implements. In ants the mandibles are highly efficient carrying organs and weapons of defense. The *maxillæ* form the lateral conspicuous wings of the suctorial parts; the *lacinia* and *galea* are fused and the *maxillary palpi* are minute. The *labium* is represented by the long structures to the right and left of the middle tube which is probably the *hypopharynx.* The hypopharynx terminates in a spoon-like labellum or *bouton* which completes the lapping character of the subtype.

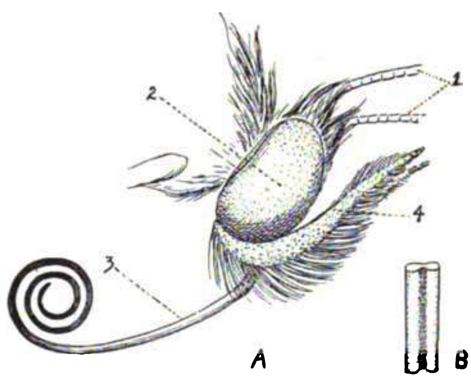

FIG. 32. — Head and mouth parts of a butterfly (*Vanessa sp.*). (*a*) Side view. Suctorial, coiled tube, Lepidopteron type. (1) antennæ, (2) compound eye, (3) proboscis, consisting only of the galeæ, (4) labial palpus. (The labrum is not visible in side view.) (*b*) Section of proboscis showing double nature.

Lepidopteron Type. — This type, represented by the commoner butterflies and moths, is typically a coiled, sucking tube capable of great elongation. Taking the cabbage butterfly (*Pontia rapæ*) as an example (Fig. 32) the *labrum* is seen to be greatly reduced, the mandibles absent. (These may be weakly present in the lower Lepidoptera.) The maxillæ are apparently only represented by the *galeæ,* which by close approximation of their inner grooved surfaces form the long coiled proboscis. The double structure of the proboscis can be easily demonstrated by manipulation. The *labium* is represented by the *labial palpi.*

Orders of Insects Arranged According to Mouth Parts with Type of Metamorphosis Indicated

I. *Orthopteron type.*[1] Biting or chewing mouth parts.

1. *Order Thysanura*, — Bristletails, springtails, *et al.*, mouth parts withdrawn in cavity of head; primitive metamorphosis.
2. *Order Ephemerida*, — May flies, — mouth parts vestigial; simple metamorphosis.
3. *Order Odonata*, — Dragon flies and damsel flies, — simple metamorphosis.
4. *Order Plecoptera*, — Stone flies, — simple metamorphosis.
5. *Order Isoptera*, — White ants, — simple metamorphosis.
6. *Order Corrodentia*, — Book lice, *et al.*, — simple metamorphosis.
7. *Order Mallophaga*, — Biting lice, — simple metamorphosis.
8. *Order Orthoptera*, — Grasshoppers, cockroaches, *et al.*, — simple metamorphosis.
9. *Order Euplexoptera*, — Earwigs, — simple metamorphosis.
10. *Order Neuroptera*, — Dobson flies, ant lions, aphis lions, *et al.*, — complex metamorphosis.
11. *Order Mecoptera*, — Scorpion flies, — mouth parts prolonged into a beak with mandibles at the tip; complex metamorphosis.
12. *Order Trichoptera*, — Caddis flies (moth-like); complex metamorphosis.
13. *Order Coleoptera*, — Beetles, — complex metamorphosis.

II. *Physopodan type.* Biting in structure but sucking in function; represents a transitional form between the biting and sucking insects.

14. *Order Physopoda*, — Thrips, — simple metamorphosis.

III. *Hemipteron type.* Elongated, typically 3 or 4 segmented proboscis (unsegmented in the true lice), snugly enclosing stylet-like organs; piercing and suctorial.

15. *Order Hemiptera*, — Cicadas, bedbugs, cone-noses, *et al.*; simple metamorphosis.

IV. *Dipteron type.* Unsegmented proboscis, which may or may not contain piercing stylets.

16. *Order Diptera*, — mosquitoes, flies, *et al.*; complex metamorphosis.
    - *a.* First subtype. — The mosquito, — loosely ensheathed, piercing, delicate, stylet-like structures, six in number, suctorial.
    - *b.* Second subtype, — The horse fly, — piercing, blade-like structures, six in number; suctorial.
    - *c.* Third subtype, — The stable fly, — closely ensheathed, piercing, heavy, stylet-like structures, two in number; suctorial.
    - *d.* Fourth subtype, — The house fly, — fleshy, non-piercing; suctorial.
17. *Order Siphonaptera*, — Fleas, — piercing mouth parts closely related to second subtype; complex metamorphosis.

V. *Hymenopteron type.* For feeding purposes the mouth parts are of a non-piercing, lapping type, but for purposes of combat and portage the mandibles are well developed.

18. *Order Hymenoptera*, — Ants, bees, wasps, *et al.*; complex metamorphosis.

VI. *Lepidopteron type.* Proboscis in the form of a greatly elongated coiled tube; non-piercing, suctorial.

19. *Order Lepidoptera*, — Moths and butterflies; complex metamorphosis.

[1] The term "Orthopteron" is here merely applied to indicate a type which varies considerably in the Order Orthoptera.

CHAPTER V

HOW INSECTS CARRY AND CAUSE DISEASE[1]

Environmental Considerations.—Manifestly it is necessary to know under what environmental conditions pathogenic organisms naturally exist in order to ascertain how the insect becomes infected and in turn is able to infect man or beast. Two factors must be considered in this connection, first, the natural longevity of the pathogenic organism, and secondly, the degree of virulence of the same when away from the normal host. For example, bubonic plague is a bacterial disease, traceable to *Bacillus pestis*, of which the rat is an important host. From this host, fleas (which are provided with piercing and sucking mouth parts) become infected and in the bodies of these insects the bacilli multiply and remain virulent; now if such infected fleas find their way to human beings, these latter in turn may become infected. It may be seen that certain environmental conditions must be considered in this connection; namely, in what part of the body of the rat are the *buboes* (plague lesions) found, and does this correspond to the distribution of the flea on the host; and if the flea sucks up plague bacilli, how long will these remain virulent; will this be long enough for the insect to leave its first host, find and infect a second host? Then again the question arises as to how the plague bacilli are introduced into the body of the human being. Is the flea the only means of dissemination? These are questions which, with others, must be answered for each case.

On the other hand malarial fever is traceable to a protozoon (Plasmodium) which cannot exist in a living condition away from the human body except in the Anopheline mosquito. Its normal environment is very restricted. In the human being it is a blood parasite, requiring a blood-sucking insect or other mechanical means to extract it together with blood. Manifestly there are many blood-sucking insects which could withdraw parasitized blood. It has, however, been abundantly proved that malaria parasites cannot reproduce sexually except in the bodies of Anopheline mosquitoes; in all other insects the parasites perish.

Similar examples involving environmental peculiarities might be cited; for example, in tuberculosis, a bacterial disease, the causative organism (*Bacillus tuberculosis*) occurs largely in a transmissible infective form away from the body in sputum. On the other hand African

[1] Students not familiar with the classification of bacteria and protozoa are referred to the appendix.

sleeping sickness, caused by a protozoon (*Trypanosoma gambiense*), occurs both in the blood of humans and certain native animals (reservoirs), and is carried by a blood-sucking fly, the tsetse fly; again, anthrax, a bacterial disease (traceable to *Bacillus anthracis*), if in the pustular form may be transmitted by blood-sucking flies of the family Tabanidæ (horseflies), as well as in other ways, while Texas cattle fever, traceable to a protozoon (*Babesia bigemina*), is transmitted solely by the tick, *Margaropus annulatus*, in which infection is hereditary.

These few examples will serve to show the necessity for having a working knowledge of the pathogenic members of the two great groups of unicellular organisms, namely the Bacteria and the Protozoa. In general it may be said that the longevity and pathogenicity of the Bacteria, when outside the host is considerably greater than in the Protozoa, owing to the highly specialized environment required by the latter.

How Insects Carry Disease. — The simplest way in which insects enter as a factor in the transmission of disease is by means of *soiled feet and mouth parts*. Any insect might accidentally become contaminated with infective sputum or fecal matter and in turn might accidentally come in contact with human foods, thus becoming an indirect factor in transmission. In this connection the normal habit of the insect must be considered, *i.e.* its breeding habits, food habits and general behavior. Thus the house fly enters as a factor in the transmission of such diseases as typhoid fever and dysentery, because of its naturally filthy habits.

A second purely mechanical method of disease transmission, though more restricted, is by means of a *soiled piercing proboscis*, in cases of certain parasitic blood diseases. In the first-mentioned method the type of mouth parts does not figure as a restrictive factor, but in the second method, in order that the proboscis may become soiled with blood, the mouth parts must be capable of piercing the skin, thus coming in contact with the blood and its contained parasites, if present. The inoculation of the second host may be purely mechanical. Insects that belong to this class of carriers ordinarily have heavy piercing mouth parts capable of drawing considerable blood, are intermittent parasites and go from host to host within a short space of time. The horsefly (Tabanus) is a good representative of this class in its chance relation to anthrax.

A more highly complicated method is involved in the transmission of bubonic plague by fleas. In this case the carrier has piercing mouth parts, is blood-sucking and an intermittent parasite. The plague bacilli when taken into the stomach of the flea multiply and do not become attenuated, but pass out *per anum* with the feces or even in undigested blood; the direct inoculation is accomplished by a "*rubbing in*" process either on the part of the host or flea. Infection may also take place by regurgitation in the act of biting.

The greatest complexity is involved in those cases in which the insect carrier is a *necessary intermediary host of the pathogenic organism, e.g.* the Anopheles mosquito in its relation to malaria. A given period of time must elapse after the mosquito imbibes infective blood before it can transmit the causative organism. This period corresponds to the time required for the plasmodium to pass through its sexual cycle in the stomach of the mosquito and find its way into the salivary glands, ready to be inoculated into the blood of the mosquito's next victim.

How Insects Cause Disease. — Insects and arachnids may relate to pathological conditions, whether serious or of little consequence, in one or more of the following ways: first, by *direct infection;* second, by *indirect infection;* third, by *internal parasitism;* fourth, by *external parasitism;* and lastly, by *venoms.* The same species may fall as legitimately into two divisions, as for example, the Texas fever tick, which if not infected with the causative organism of the fever need only be considered as an external parasite, but when the causative fever organisms are present in the tick, would relate it also to direct infection.

Direct Infection. — Direct infection under ordinary conditions could only be produced by an insect or arachnid possessing piercing mouth parts, and here no special order or larger group can well be referred to, inasmuch as closely related insects may have very different mouth structures. The common house fly and the stable fly, for example, belong to the same family (Muscidæ), therefore are closely related, yet have widely different mouth parts; though both are suctorial, the former is unable to pierce the skin, whereas the latter can do so with ease.

By direct infection is meant the introduction of a pathogenic organism, whether bacterial or protozoan, into the circulation of a higher animal. The Anopheles mosquito is therefore related to this manner of transmission, because it introduces the malaria parasite (*Plasmodium*) directly into the blood stream of man. The same is true of the Stegomyia (Ædes) mosquito and yellow fever; the Glossina flies and sleeping sickness; horseflies and anthrax. Direct infectors are usually temporary, intermittent ectoparasites permitting transfer of activity from animal to animal.

However, there is still a possibility for an insect with mandibulate mouth parts or with non-piercing haustellate mouth parts to infect an animal as directly as one possessing piercing mouth parts. Thus the house fly may, by means of its feet and mouth parts, transmit septicaemic infection to an animal undergoing surgical operation or suffering from an open wound.

Indirect Infection. — This form of infection relates chiefly to enteric diseases in the causation of which the pathogenic organism is deposited upon food by the insect. Thus the food is first infected and with it the pathogenic organism is implanted within the alimentary canal of the victim; in this way the insect is only concerned indirectly. The house fly, one of the grossest transmitters of enteric diseases, is only so because of accident of habit and structure, feeding as it does indiscriminately on excrement and food of higher animals, and with proboscis and feet so constructed as to certainly collect germ-laden particles of excrement.

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Insects possessing mouth parts not adapted to piercing the skin (whether biting or sucking) may relate to this form of infection, and indeed any insect or arachnid may be an indirect carrier by accident. Furthermore, insects ordinarily relating only to indirect infection may produce direct infection of certain kinds where there is access to an open wound as already explained.

Internal Parasitism. — There are no insects so far as is known which spend their entire life history in the form of internal parasites. There are, however, a number which pass their larval period (period of growth) within the alimentary canal or in the muscle tissue of higher animals. The best-known representatives of this group are the botflies and the warble flies, the former found in the stomach and intestine of equine animals, while the latter are found in the muscle tissue of bovine and equine animals, rodents, and sometimes man. The harm done by internal insect parasites is of various kinds, *e.g.* irritation, impaired digestion, loss of nutrition, etc.

External Parasitism. — The most important and most abundant external parasites of man and of the domesticated animals are found among the insects and arachnids. Very serious and often fatal results are due to this form of irritation, and the loss of blood due to an abundance of blood-sucking species must not be overlooked. External parasites may be either permanent or temporary in relation to the host. The commonest permanent parasites are the biting and sucking lice, which are usually transferred from host to host by close association of mammals while sleeping together in close quarters, or while in copulation; in poultry generally while roosting. The sucking lice are also important disease vectors, which involves transfer of activity from animal to animal, usually brought about by close association, interchange of garments and toilet articles. Thus lice are carriers of typhus fever and relapsing fever, infection being brought about by the bite or by crushing the parasites and scratching or "rubbing in" the infective agent. Temporary intermittent ectoparasites are the most important of all disease carriers, owing to their habit of changing hosts. It may well be seen that herein lies the danger of transmitting infectious diseases from animal to animal. The temporary ectoparasites are well represented by the fleas, bedbugs and certain ticks.

Insect Venoms. — Another form of irritation is produced by the introduction of a specific venom by contact, pierce or sting. Many insects produce severe irritations by their bites, which fact can be accounted for by the presence of a venom-secreting gland, often salivary. The cone-noses or kissing bugs (Reduviidæ) inflict a very painful wound aggravated by a poison; other insects produce nettling when handled, *e.g.* the blister beetles (Meloidæ); and the familiar sting of the bee (Apidæ) and wasp (Vespidæ) is chiefly painful because of the injection of specific poisons.

CHAPTER VI

COCKROACHES — BEETLES — THRIPS

A. The Cockroaches

Order Orthoptera, Family Blattidæ

Few insects excepting the lice are looked upon with as much disgust as are the cockroaches. The mere suggestion that these insects might be present in a dwelling or place of business leads usually to a rough snubbing. Such is the experience of inspectors whose duty it is to keep a record of vermin and noxious insects in connection with health movements in certain cities. A flat denial is often forthcoming in the face of the strongest evidence.

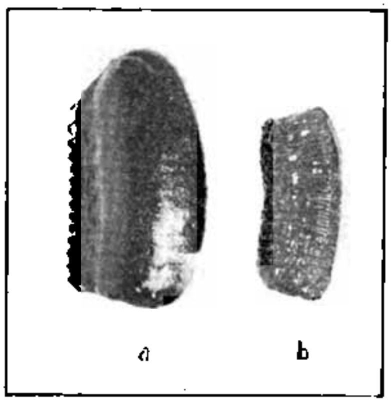


Fig. 33. — Egg cases (oötheca) of cockroaches. (*a*) oriental roach; (*b*) croton bug. × 3.

Habits. — Cockroaches belong to that group of insects which attack human food in all degrees of preparation. Not only human food but all manner of organic material is attacked; nothing seems to be exempt, as all will attest who have spent some time in tropical or subtropical sections in particular. They are omnivorous, with a special inclination toward starchy and sugary materials. Where everything seems to be shipshape during the daytime, at night one can hardly take a step without hearing that ominous crackling underfoot as these creatures are crushed by the tread. During the day the cockroaches are in hiding in dark corners, behind wainscoting, under boxes, in cupboards and the like, regardless (yes, perhaps with predilection) of filth.

Life History. — There seems to be little difference in the life history of the various species of cockroaches. The female is often seen with a chestnut-colored, chitinous object (Fig. 33), partly protruding from the terminal abdominal segment. This is the egg case, or *oöthecum*, which is carried around by the female often for several weeks until the young are ready to hatch. These egg cases appear at all times of the year, hence it seems that there is no special season to which egg deposition is limited. The young roaches are quite active from the beginning, having the same food habits as the adults. Their

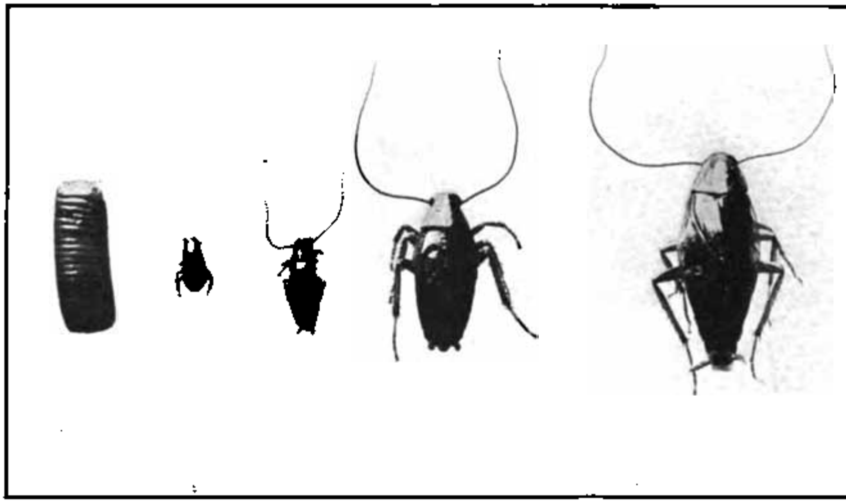


FIG. 34. — The croton bug (cockroach), *Blatella (Ectobia) germanica*, in various stages of development. The adult female is shown with egg case or oötheeum in normal position protruding from the terminal abdominal segment. × 2.

metamorphosis is simple, quite like that of the grasshopper, requiring about one year to reach maturity, probably somewhat less in tropical and subtropical countries. The writer has kept cockroaches (the croton bug) under observation in glass jars for many weeks in order to note their growth, which was seen to be very slow. As the individuals molt, the shed skins are eaten, as are also the dead roaches, — an economical habit.

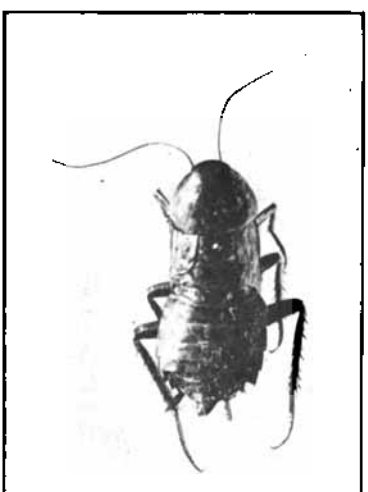


FIG. 35. — The oriental roach, *Blatta orientalis*. × 1.3.

Structural. — Cockroaches have characteristically, dorsoventrally, flattened bodies, generally of a chestnut brown to black color. The wings of the males are usually well developed, but the females often have mere vestiges. While the winged forms possess the power of flight, the group as a whole is running in habit and the individuals can cover ground in this way with marvelous rapidity. The mouth parts are of the biting type, distinctly orthopteron.

Species and Distribution. — As household pests cockroaches are widely distributed, brought about chiefly through maritime trading; holds of vessels as well as the crew's sleeping quarters are oftentimes overrun with these miserable pests. The most widely distributed species are the croton bug, *Blatella germanica* Linn. (Fig. 34), and the oriental roach, *Blatta orientalis* Linn. (Fig. 35). The former is one of the smallest species, measuring about five-eighths of an inch to the tip of the wings, which are present in both sexes. This species is evidently the most common form along the north Atlantic and north Pacific coasts, as shown by observations made in Boston, New York and San Francisco. The name croton bug has been applied to this insect because of its appearance during the construction of the Croton water system of New York City. In color the insect is a muddy brown with two longitudinal stripes on the pronotum.

The oriental roach is an inch or more in length and is very much darker than the croton bug, hence is often called "black beetle" (the term beetle being wrongly applied). The female has vestigial wings, while in the male these organs are short, reaching not quite to the tip of the abdomen. This form is more common in the central states of the United States and according to Kellogg extends as far west as the great plains. It also occurs in California.

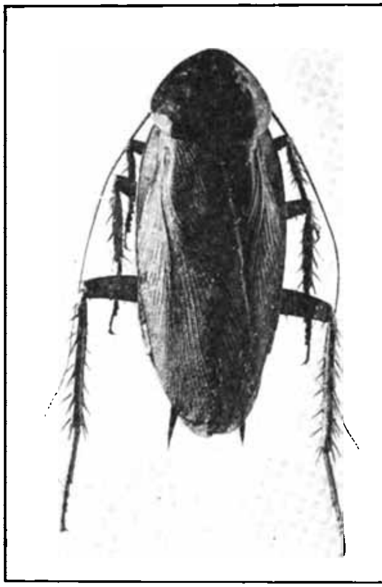


Fig. 36. — The American cockroach, *Periplaneta americana*. × 1.3.

Another house-infesting species is the native American cockroach, *Periplaneta americana* Linn. (Fig. 36), a light chestnut-colored species, which reaches a length of an inch and a half and has long wings in both sexes. This is also a common species in the middle and western states, being especially abundant in Mexico and Central America. It resembles a slightly shorter species occupying about the same territory in the United States, namely, *Periplaneta australasiæ* Fabr. (Fig. 37), which differs further in that the Australian roach has a yellowish border around the pronotum, extending partly down the outer margins of the wing covers. Our commonest native outdoor species is *Ischnoptera pennsylvanica* De G. To these common forms might be added a list of exotic roaches constantly coming to our shores on shipboard from the Orient and elsewhere, but which have never secured a foothold.

Life History and Habits of the Croton Bug. — The croton bug is nocturnal in habit, but may be seen roaming about during the day, although its activity is then limited. Generally the roaches collect in huddled groups during the day and remain inactive. Their main requirements for activity are, first, a fairly high temperature; secondly, darkness; and lastly, a supply of food. Roaches are commonly encountered in kitchens, galleys, restaurants, bakeries, etc. These insects are omnivorous, favoring starchy and sweet materials; they may also feed on excrement and will readily devour their dead brethren and cast-off skins.

The eggs of the roach are laid in pairs (13 pairs usually) in an egg case, or oöthecum (Fig. 34), which, when filled, protrudes from the abdomen of the female. The females may evidently carry these cases about with them two months or more, when they are finally deposited in some dark crevice, and the young roaches or nymphs hatch out in twelve days or less. The young roaches are at first almost white and transparent, but soon become brownish and resemble the adults except for size and absence of wings. The young roaches molt soon after emergence from the egg case and again in about four weeks. There are apparently about six molts before the roaches are mature, and certainly a year or more is required before this is accomplished.

FIG. 37. — The Australian roach *Periplaneta australasiæ*. × 1.12.

Relation to Disease Transmission. — Cockroaches have long been looked upon with some suspicion as possible carriers of disease and are certainly regarded with much disgust by everybody. If the house fly is such a potent transmitter of infection, why not the cockroach, at least to a large degree? While the house fly is active in the daytime, walking over prepared human food, depositing thereon its load of bacteria, the cockroach is actively engaged, under cover of night, in a similar performance. The two insects by analogy must relate to the transmission of bacteria in a similar manner, *i.e.* must collect bacteria on their feet and mouth parts by crawling and feeding on filth which may be charged with bacteria, and depositing these on human food, while in the act of feeding.

The cockroach has biting mouth parts like the grasshopper, hence could not relate to the transmission of disease by direct inoculation, as does the stable fly, for example, which has piercing mouth parts. If the structure of the cockroach is such that it can pick up bacteria easily, and if it can be shown that the cockroach invades places where infective material, such as sputum or excrement, is found, then a chain of strong circumstantial evidence could be produced that the roach is a factor in the dissemination of such diseases as tuberculosis, dysentery, cholera and probably typhoid fever. The food habits of the roach are certainly such that there is ample opportunity for the contamination of the food of man.

Comparing the feet and mouth parts of the house fly and the croton bug, it will be seen at once that the latter is far less adapted to the collection of filth, inasmuch as the feet, especially, are not so well provided with spines and hairs as are the feet of the house fly. However, the weight of the insect and surface in actual contact with infective material partly compensates for the above structural deficiency.

Can the Roach Pick up Specific Bacteria? — In order to answer this question one of these insects was allowed to crawl over a culture of *Bacillus pyocyaneus aureus*, a green chromogen, in a test tube. The growth on the agar in this tube was not very profuse. The insect was next transferred to a sterile agar plate upon which it was permitted to walk one minute. The roach was then liberated and transferred to a second plate for one minute, and then to a third plate in a similar manner. The agar plates were then incubated for 24 hours at a temperature of 37° C. At the end of this time a good growth of the green chromogen, *Bacillus pyocyaneus aureus*, had developed on all three plates.

This experiment goes to prove that the legs of the roach are constructed so as to enable it to pick up bacteria of a given kind and enough to heavily inoculate at least three plates.

Can the Roach Carry Specific Bacteria to Human Food? — Having determined that the roach can pick up known bacteria, the next thing was to prove that it could deposit these same organisms on human food. In order to do this one grain of sugar was exposed to a cockroach that had previously walked across an agar plate culture of *Bacillus pyocyaneus aureus*, the same chromogen used above. The insect remained with the sugar, feeding on it, for three minutes. The sugar was then dissolved in 5 cc. of sterile water and plated on three agar plates, using 1 cc. of the solution for each. The plates were incubated for 24 hours at 37° C. *B. pyocyaneus aureus* was recovered on all three plates, the growth on none being scanty. The recovery of the test culture in the sugar solution showed that the contaminated cockroach could in turn contaminate the food over which it crawled and upon which it fed.

The Bacterial Population of the Croton Bug. — Six individuals were selected from a collection of roaches taken from various localities and permitted to crawl for one minute over six sterile agar plates (one roach for each plate). These plates were incubated for 48 hours at 37° C. Each plate showed a good growth, the colonies on examination proving to be saprophytic without exception.

To secure an approximate estimate of the number and kind of bacteria carried by roaches, two of these insects were treated as follows. After sterilizing pipettes, forceps, tubes, etc., 5 cc. of distilled water was placed in each of the five test tubes. Into these tubes were placed the legs and antennæ of the roaches, — the posterior pair of legs of one roach into one tube, those of the other roach in a second tube, the antennæ of both roaches in a third, and the remaining pairs of legs of the first roach in the fourth and the remaining pair of legs of the other roach in the fifth tube. The stomach contents were plated on agar. The tubes were shaken vigorously for three minutes in order to wash the parts well and then 1 cc. of the water in each tube was plated on agar and incubated 24 hours at 37° C. The results were all positive, as the following table (Table I) indicates:

TABLE I

SHOWING NUMBER AND KIND OF BACTERIA CARRIED ON INDIVIDUALS OF THE CROTON BUG

No. of the Roach	Part of the Roach Plated	Bacterial Count per cc.	Kind of Bacilli Present
1	Posterior pair of legs	1200+	(a) *Staphylococcus albus* (b) Non-spore-bearing bacillus
2	Posterior pair of legs	1600+	(a) *Staphylococcus albus* (b) Non-spore-bearing bacillus
1	Remaining legs	950	(a) *Staphylococcus albus* (b) Small non-spore-bearing bacillus (c) Spore-bearing air bacillus
2	Remaining legs	1200	(a) Spore-bearing air bacillus (b) *Staphylococcus albus*
1–2	Antennæ	384	(a) Spore bearing air bacillus (b) *Staphylococcus aureus* Yellow pigment
1	Stomach contents	14	(a) Minute bacilli (unidentified)
	Total	5348+	for a dilution of ⅕
$5 \times 5348^{+} \div 2 = 13{,}370^{+}$ bacteria, — minimum number present on each roach			

From the above table it will be seen that each roach carried on its feet and antennæ and in its stomach a minimum of 13,370 bacteria. While this does not represent a fair estimate for all roaches, since only two individuals were used, we are here shown that the roach can carry a large number of bacteria. Esten and Mason (Storrs Agric. Exp. Sta., Bull. No. 51) have shown that the number of bacteria carried by a fly range all the way from 550 to 6,600,000, with an average of one and one fourth million bacteria on each. Thus by comparison it may be seen that the roach probably carries fewer bacteria.

It is furthermore interesting to note that there were more bacteria on the single pair of posterior legs than on the remaining two pairs combined. This is probably explained by the use the cockroach makes of its hinder pair of legs. The tibiæ and tarsi are in contact with the surface on which the insect walks, being parallel with the body. Very often the insect stands on the hind pair of legs, with the remaining legs barely touching the surface. The fore legs are also frequently brushed by the antennæ.

Environmental. — The last link in the chain of evidence against the cockroach is its normal environment, which gives the insect an opportunity to contaminate itself with pathogenic organisms, if present. Such an environment would be an accessible insanitary privy, close to the kitchen or pantry, in which case there is at least the possibility of the transference to the food of man of one of the causative organisms (bacillary) of dysentery, diarrhea and cholera and still more remotely of typhoid fever.

Conditions favoring the transmission of the tuberculosis bacillus are relatively more common. Two instances may be cited. These existed in the forecastle of two vessels. On these two vessels no separate mess rooms were provided for the sailors, their food being served in the same room in which they slept. Bread, butter and sugar were usually left uncovered on the table, readily accessible to cockroaches, which swarmed over floors and walls. Sailors occupying the rooms were in the practice of constantly spitting on the floor. If one or more of these sailors should be tubercular, there is at least the possibility of germ transmission by the roach to the food. A third instance may be mentioned, that of a certain roach-infested residence occupied by a consumptive in the last stages of the disease. This patient did not use sputum cups, and although belonging to a refined family had the pernicious habit of spitting in the darker corners of the room and behind pieces of furniture. In this house lived a half dozen students who also took their meals there. Roaches were commonly seen in the room in which the patient lived and roaches swarmed in the pantry and kitchen at night. Surely here existed a condition that favored the transmission of tubercle bacilli. Unfortunately the reputation of this house in one of the more select districts of the city was of more importance than the lives of the inmates of the house.

Other Considerations. — The fact that roaches also feed on fecal matter may lead to further complications, which, owing to lack of experimental evidence, cannot be considered here further. However, it was very early known that cockroaches may become infected with *Filaria rytipleurites* Delonchamps of the rat, by feeding on rat feces, and that other rats may become infected in turn by feeding upon such roaches. Galeb in *Comprend Rendu* (1878) reports his observations upon the transmission of this nematode. He discovered numerous parasites in the "adipose tissue" of the roach *Blatta orientalis*, which were found to be identical with nematodes found in the rat, *Mus decumanus*. He also found hair of the rat in the alimentary canal of the roach. On feeding rats (*Mus rattus*) with infected roaches and examining them after the expiration of eight days, he found the parasites in the folds of the mucous membrane of the stomach. Several nematodes (three females and one male) had already developed sexual organs. More recent experimental evidence indicates that the roach is almost certainly the intermediary host of this nematode.

Control. — Numerous methods have been evolved to combat the cockroach, and it is quite certain that this insect can be controlled in dwellings, restaurants and the like. One method which has been found useful for the larger less abundant form is the trap. This consists of a deep, smooth-walled vessel (fruit jar or the like) into which is placed a favorite roach food, such as chocolate, or molasses (stale beer or ale are also recommended). Sticks leading to the top of the jar must be provided in order that the roaches can easily reach the mouth, and in their endeavor to get at the food tumble into the trap. If there is a liquid in the trap, the roaches are drowned; otherwise they must be killed by scalding.

Trapping methods are least successful in the control of the croton bug; it is certainly far more wary than the larger species. The ordinary glass-jar-trap method employed for the larger species is not effective. The croton bug can crawl up the sides of a glass jar without difficulty and thus make its escape. A dark box trap is preferable with one or more tubular pasteboard entrances projecting both inside and outside. The mouth of the tube inside the box must be guarded either with a single trap door or adhesive substance around the outside of the tube and immediately adjacent to the mouth to prevent the roaches from escaping after feeding on the bait. The box may be baited with sugar, sweet chocolate, a little stale beer or the like. After the roaches have been captured they are shaken out through a lid into kerosene or hot water. The box is then once more baited and placed in position.

More satisfactory results are obtained by means of poisons. When the word *poison* is used in this connection it does not necessarily imply that it is a poison also to human beings, since there are some materials which act in this way when eaten by insects but are non-poisonous to human beings, except, of course, when taken in large quantities; among such materials are borax and formalin. Borax is frequently used as an ingredient in the preparation of roach and ant poisons. Thus equal parts of chocolate, or powdered sugar, and borax well mixed (this is important) provide an excellent roach powder. This powder should be placed in little heaps or in windrows easily accessible, or may be sprinkled in the crevices whence the insects come. Persian insect powder or pyrethrum stupefies the insects. Dusting the haunts of the roach liberally with flowers of sulphur also proves effective as a repellent. Two methods mentioned by Felt[1] are the following: "The smoke of burning gunpowder is very obnoxious and deadly to roaches, particularly the English roach. The moistened powder should be molded into cones, placed in an empty fire-place and ignited. It is particularly valuable in the case of old houses." A second method, viz.: "A relatively simple method, described by Mr. Tepper of Australia, is to mix plaster of paris, one part, and flour three or four parts, in a saucer and place the preparation about the haunts of the pests. Near by there should be a saucer containing a little water and made easily accessible to the roaches, laying a few sticks as bridges up to the rim. The insects eat the mixture, drink the water and soon succumb."

Fumigation with hydrocyanic acid gas, carbon bisulphid or sulphur may be resorted to with much success; however, should not be undertaken without experienced assistance, since the behavior of these gases must be fully understood.

B. The Beetles

Order Coleoptera

The beetles may easily be distinguished from other insects by the following characters: the mouth parts are of the biting type, mandibles strongly developed; two pairs of wings are present of which the forward pair is hardened and does not overlap at the tip; the ventral portion of the abdominal segments consists of chitinous plates extending at least halfway round the body. (In other insects these ventral plates are much shorter as a rule.)

The metamorphosis of Coleoptera is complex (egg, larva, pupa, imago) with the occurrence of hypermetamorphosis in a number of species. The larvæ of this order are commonly called "grubs" and may be recognized by the presence of three pairs of rather feeble legs.

Only a few families of this great order of insects concern us, and only those which by habit come in contact with diseased animal carcasses, or attack other living animals or which possess medicinal properties.

Scavenger Beetles. — All the scavenger beetles are of interest in this connection since the habit of feeding on dead animal matter might accidentally bring them in contact with the infection. Infection may be carried in two ways, namely, first mechanically on the body, legs or mouth parts, or secondly, in the excreta. The latter method involves attenuation in that the pathogenic organism may become reduced in virulence in its passage through the alimentary canal of the insect.

Among the families of scavenger beetles are the Staphylinidæ or rove beetles (not all animal feeding), recognized by the abbreviated condition

[1] Felt, Ephraim Porter, 1909. Control of Household Insects. New York State Museum, Bulletin No. 129 (Albany).

of the wing covers (elytra), thus exposing the abdomen dorsally, and giving these beetles a larval or worklike appearance, augmented by the flexibility of these parts. The functional wings are folded up and concealed under the elytra. The range in size in this family is enormous. One very small species in the act of swarming is known to get into the eyes of people when driving, cycling or motoring, causing a severe burning sensation by means of the vile-smelling body secretions. The species commonly met with on turning over carcasses, hides, heaps of bones and other animal rubbish, belong to two genera; namely, Creophilus (Fig. 38 left) and Staphylinus (Fig. 38 right), which include species ranging from one half to one inch in length. A second family to be considered are the Silphidæ, or sexton beetles, also known as carrion beetles. In habit these insects are more decidedly scavenger than the preceding, feeding almost exclusively on dead flesh, both as larvæ and adults. Again two genera will serve to illustrate the commoner forms, namely, Silpha (Fig. 39 left) and Necrophorus (Fig. 39 right). These two genera are well illustrated as to relative size and general shape by the accompanying figures.

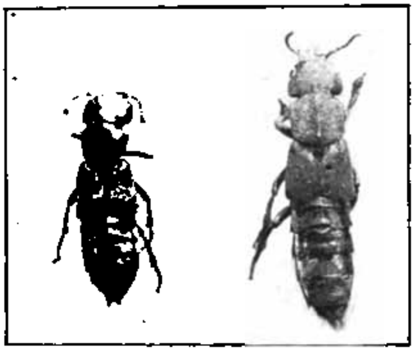


FIG. 38. — Rove beetles (Staphylinidæ). *a.* Creophilus; *b.* Staphylinus. × 1.5.

A third family, the Histeridæ, is composed of a group of small-sized, short, shining, black beetles commonly found about decomposing animal matter.

The fourth family, Dermestidæ, also includes only small forms, about one third of an inch and less in length. In shape they are elliptical, usually dark grayish or brownish in color. Skins and other animal specimens in museums are often ruined by the museum pest, *Anthrenus museorum* Linn. or *Anthrenus verbasci* Linn., if proper precautions are not taken. This damage is practically all done by the larvæ, as is the case with the larder beetle, *Dermestes lardarius* Linn. and *D. vulpinus* Fabr. and the carpet beetle, *Anthrenus scrophulariæ* Linn.

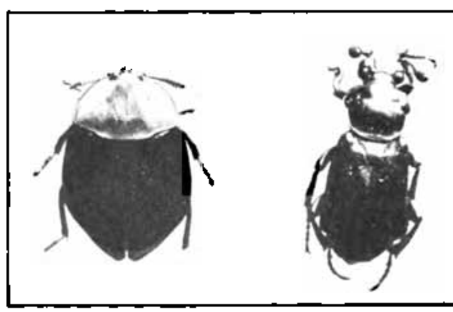


FIG. 39. — Sexton beetles (Silphidæ). *a. Silpha americana*; *b. Necrophorus sp.* × 1.5.

Relation to Disease. — Where hides taken from anthracic animals or the carcasses are attacked by scavenger insects it is more than likely that there will be danger from this source. The following statements taken from Nuttall[1] bear directly on this subject, viz. " Proust (1894), in examining goatskins taken from anthracic animals, found quantities of living *Dermestes vulpinus* upon them. He found virulent anthrax bacilli in their excrements, as also in the eggs and in the larvæ. It is evident from this that these insects which feed on the skins permit the anthrax spores to pass uninjured through their alimentary tract. Heim (1894) also had occasion to examine some skins which were suspected of having caused anthrax in three persons engaged in handling the leather. He found larvæ of *Attagenus pellio* Linn., *Anthrenus museorum* Linn. (both Dermestidæ) and Ptinus, also fully developed insects of the latter species on the skins. All these insects had virulent anthrax bacilli (spores) on their surface and in their excreta, from which Heim concludes they might spread disease. He says the excreta are very light and easily scattered by the slightest current of air. Heim does not believe the bacilli multiply in the bodies of these insects, but that the latter may be dangerous through their scattering the spores about."

FIG. 40. — Thorn-headed worm, *Echinorhynchus gigas*, of swine, requiring a May beetle (Lachnosterna or Melolontha) as intermediary host. × 1.

May Beetles and Thorn-headed Worms.—May beetles or cockchafers (Family Scarabæidæ) are known to be intermediary hosts both in the larval and adult stages of the thorn-headed worm (Fig. 40), *Echinorhynchus gigas* Goeze, a parasite of swine also said to occur in man in rare cases. This nematode worm in its adult stage measures from 20 to 30 cm. in length and about 3 to 5 mm. in thickness, and inhabits the small intestine of its host. The eggs are deposited in this habitat and pass out with the feces which may be swallowed by the larvæ of the cockchafers. These are often extremely abundant among the rootlets of grass in heavily sodded pastures, and swine with free range are exceedingly fond of these grubs, in search of which they diligently root up the soil with their snouts. Thus every opportunity is given for the grubs to become infected and in turn the swine.

[1] Nuttall, George H. F. On the Rôle of Insects, Arachnids and Myriapods, as Carriers in the Spread of Bacterial and Parasitic Diseases of Man and Animals. Johns Hopkins Hospital Reports, Vol. VIII, Nos. 1–2, 1899.

After the ova have been ingested the larvæ hatch in a few days within the intestine of the insect and proceed to burrow through the intestinal wall and into the muscles, where they are said to encyst themselves. In Europe the intermediary host is commonly *Melolontha melolontha* Linn. (*vulgaris* Fab.) and *Cetonia aurata* Linn. May beetles of the genus Lachnosterna (Fig. 41) (according to Stiles, *Lachnosterna arcuata* Smith and others) are probably all more or less concerned. The life history of nearly all May beetles is quite long, the larval stage alone often requiring nearly three years.

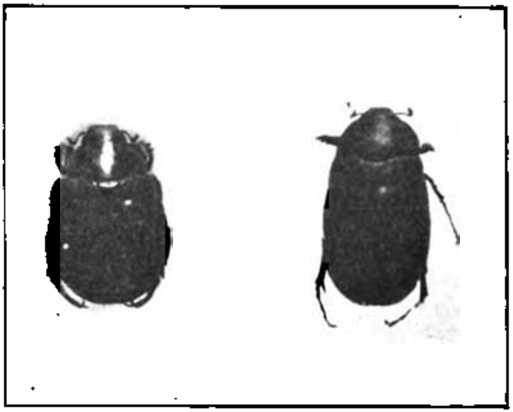


Fig. 41. — May beetles or cockchafers, *Cotalpa lanigera* (left) and *Lachnosterna fusca* (right). Serve as intermediary hosts for the thorn-headed worm of swine. × 1.2.

In districts infested with the thorn-headed worm a systematic crusade against cockchafers would be the logical means of control, together with the treatment of swine with vermifuges, the swine being properly coralled so that the feces can be disinfected with formalin or other effective disinfectant.

Saw-toothed Grain Beetle. — At least one case has been reported to the writer in which the saw-toothed grain beetle, *Silvanus surinamensis* Linn. (Fig. 42), of the family Cucujidæ, invaded sleeping quarters, causing great annoyance to the occupants by nibbling at and crawling about on the body. The infestation, which lasted several days, was traced to the bathroom, thence out of the house through the yard and into an old barn under the stalls, where unquestionably grain from the manger had accumulated

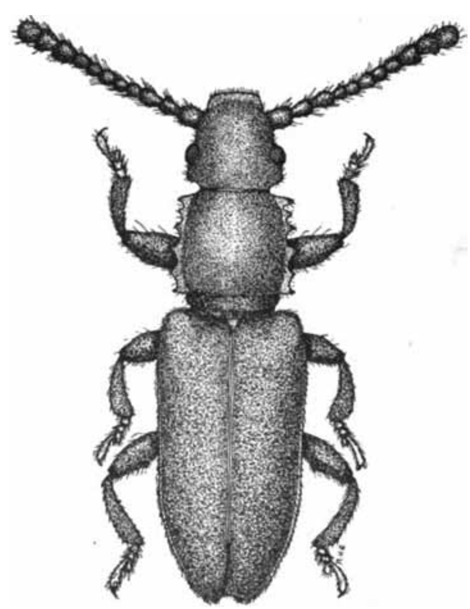


Fig. 42. — The saw-toothed grain beetle, *Silvanus surinamensis*. × 33.

and where these beetles had been bred in great numbers. The dry California summer had pretty surely driven these insects to the bathroom for water, and the attack upon the occupants of the adjoining bedchamber was merely an incidental matter. However, it is interesting to note that an instance is recorded in Braun's *Parasites of Man*, viz. "Taschenberg records this beetle as having invaded some sleeping apartments adjoining a brewery where stores were kept, and annoying the sleepers at night by nipping them in their beds."

Cantharidin, Spanish Fly. — Although a few other insects secrete vesicating fluids, the principal source for medicinal purposes is the group of insects known as the blister beetles (Meloidæ) of which the Spanish fly, *Lytta vesicatoria* Linn. (Fig. 43), is the most important member.

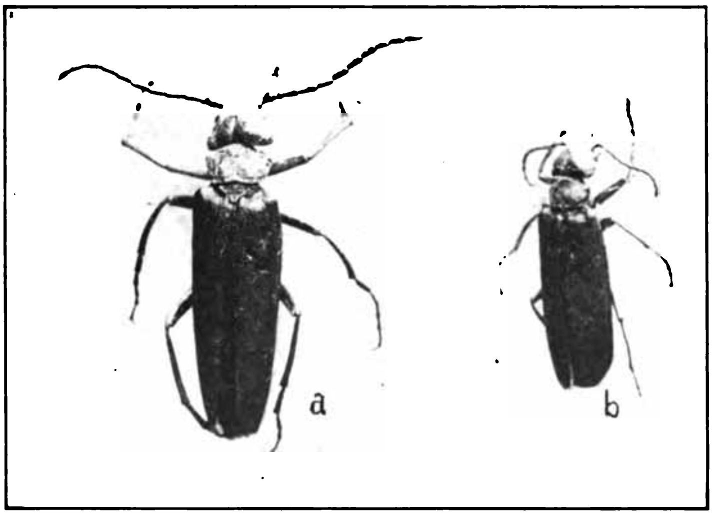


FIG. 43. — The Spanish fly, *Lytta vesicatoria*. *a*. female ; *b*. male. × 2.1.

This beetle is a European form found most abundantly during a certain season of the year in Spain, Southern France and even at times in Germany; Petrograd supplies also a large quantity of superior cantharidin. The Spanish fly possesses a fine golden green or bluish color, ranges from ½ to ¾ of an inch in length and makes its appearance quite suddenly in early summer, when it may be collected by the hundreds, clinging principally to such vegetation as the ash, privet and lilac. The peculiar hypermetamorphosis of these insects and their larval habits give to them some obscurity during their early development and the sudden appearance and equally sudden disappearance, owing to short adult life, lent the belief that they were migrating forms.

The collection and preparation of the beetles provides an occupation for many persons during the brief period. This process also requires special precautions owing to the vesicating properties of the insects.

The best quality of cantharidin produced from the pulverized beetles is the result of special care in the drying, which must be gradual. Of cantharidin, Sollman[1] (p. 705) says it is the most important local irritant. "It is a crystalline principle, the anhydrid of cantharidic acid. It combines readily with alkalines, forming soluble salts . . . it was isolated by Robiquet in 1812 from the Spanish fly . . . *Lytta vesicatoria*. . . . Cantharidin is readily absorbed from all surfaces. Even when applied to the skin, sufficient may be absorbed to irritate the kidneys, so that fly blisters are contraindicated in nephritis. It is excreted mainly by the kidneys. It irritates the gastro-intestinal tract even when injected hypodermically so that some must be excreted by this channel. . . . Cantharidin penetrates the epidermis quite readily and produces violent but superficial irritation. This results in vesication. Very small quantities suffice for this purpose, $\frac{1}{10}$ mg. cantharidin . . . will produce blisters on the human skin in the course of a few hours."

As to *therapeutic uses* the same author states: "Cantharis is the most useful of vesicants. . . . The vesicant action of cantharides develops rather slowly. (It) is one of the most useful remedies in the treatment of baldness. It is used in the form of tincture, very greatly diluted with alcohol. For treatment of impotence Cantharis is one of the most certain, acting through reflex irritation from the urethral mucous membrane. *It is, however, quite dangerous, since effective doses are apt to set up considerable nephritis.*"

C. Thrips

Order Physopoda

Thrips and Sneezing. — The introduction of foreign particles into the nostrils causes sneezing, this phenomenon being easily induced by irritation of the mucous membrane of the nasal chambers. Such a paroxysm often follows when a flower is held close to the nose and a strong inhalation is made to receive the odor. This strong inhalation frequently brings with it small insects which were crawling about on the petals of the blossom. Insects habitually inhabiting blossoms are most likely to be the guilty ones and of these the commonest minute forms are members of the order Physopoda (Thysanoptera) commonly called thrips.

Characteristics. — These rather active insects are characterized by their small size (1 to 2 mm.) together with the following unique structures, viz.: the foot terminates in a bladder-like organ, whence the term Physopoda; the wings are narrow, but this narrowness is compensated for by a great development of long, closely set fine hairs along the margins of each wing, whence the name Thysanoptera (bristle

[1] Sollman, Torald, 1908. Textbook of Pharmacology, 1070 pp. W. B. Saunders Co.

wings) (Fig. 44*a*). The mouth parts are also distinctive as already explained.

Systematic. — The order is divided into two subdivisions based on the form of ovipositor, — tubular in Tubulifera (Fig. 44*b*); saw-like in Terebrantia (Fig. 44*c*). In the former subdivision the ovipositor is cylindrical, telescoping in the last segment of the abdomen and ending in a circlet of bristles; the following commoner forms are representatives of this division: *Phleothrips verbasci*, mullein thrips; *Phleothrips nigra*, clover thrips, black in adult but bright red in the larval stage. The second subdivision, Terebrantia, is represented by *Euthrips tritici* Fitch., orange-yellow in color, and found in many blossoms according to the time of blossoming (apple blossoms, strawberry blossoms, citrus blossoms, and grasses); *Euthrips striatus* Osb. is the grass thrips, also yellow, but smaller than *Eu. tritici* Fitch.; *Euthrips pyri* Dan. is the pear thrips of the Santa Clara Valley and elsewhere.

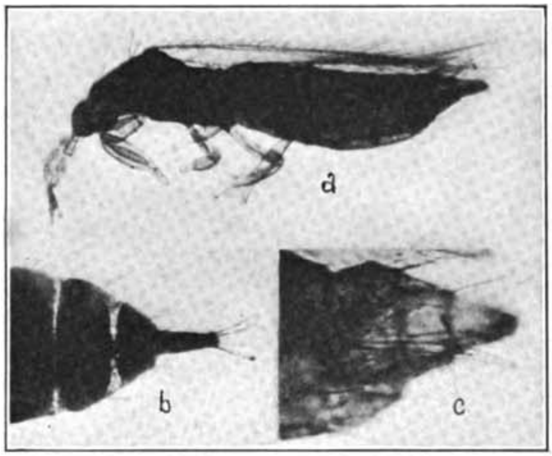


FIG. 44. — Thrips, Order Physopoda. (*a*) Shows characteristic bladder feet and bristle wings. × 28. (*b*) Tubular ovipositor of Tubulifera. (*c*) Saw-like ovipositor of Terebrantia.

CHAPTER VII

THE LICE

A. The Biting Lice

Order Mallophaga

Characterization. — This group of parasites is not easily distinguishable from the true sucking lice (the Pediculi) which they closely resemble in habit and general form. In mouth parts they are, however, very different; the former are provided with mandibles used in feeding, while the latter have a long protrusible sucking proboscis. Furthermore, the sucking lice are restricted, as far as known, to mammals, while the biting lice inhabit both *mammals* and *birds*. The common name "*bird lice*" often applied to these insects is misleading for this reason. As in the sucking lice each species is usually restricted to a specific host.

The body is compressed dorsoventrally, an aid to easy locomotion among the hairs or feathers of the host. Wings are entirely absent, there being no trace of these organs present. The sharp mandibles are situated in most of the species on the ventral surface of the head, somewhat posterior to the tip, and may be seen under the microscope as conspicuous black-tipped objects.

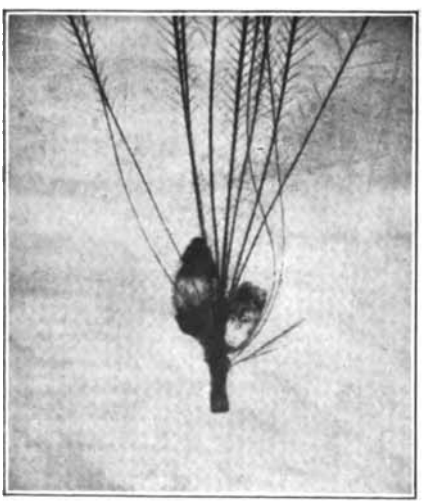


Fig. 45. — Eggs of biting lice (Mallophaga) on feathers of a bird. (Much enlarged.)

Habits and Life History. — The biting lice deposit their eggs on the hairs or feathers of the host (Fig. 45), to which they are securely attached by means of a gluey secretion. After five to eight days incubation the young lice emerge and begin their active life on the host, which they do not leave as a rule except to crawl off on to another individual of the same species, ordinarily when in close contact. Under severely infested conditions among poultry there may possibly be a migration from the host to the roosts and even to other animals, but the writer's experience has been that these infestations are generally due to poultry mites which often infest every nook and crevice of the henhouse. The biting lice are so well adapted to their habitat that they cannot well exist away from the host for more than several hours. Their food consists of exudations from the skin, epidermal scales, bits of feathers and hair. Maturity is ordinarily reached in from three to four weeks, during which time there are apparently about four or five molts, with no conspicuous change in form.

Fig. 46. — The biting dog louse, *Trichodectes latus*. × 35.

Damage Done. — The damage done by the biting lice is largely restricted to poultry, although some trouble may ensue when mammals are badly infested. The trouble is largely that of *irritation* due to the crawling about and gnawing habits of the parasites. This irritation causes the host to become restless, thereby affecting its feeding habits and proper digestion, producing weakness and susceptibility to disease. A "lousy" flock of chickens is not a profitable investment.

Fig. 47. — The biting ox louse, *Trichodectes scalaris*. × 26.

Systematic. — The biting lice (Mallophaga), of which there are over a thousand species, may be grouped into two suborders based on the following characters, — conspicuous antennæ, 3 or 5 segmented, palpi absent, rather sluggish in habit, — suborder Ischnocera; or, concealed four-segmented antennæ, palpi present, active in habit, — suborder Amblycera.

The suborder Ischnocera is subdivided into two families, viz.: Trichodectidæ, species infesting mammals, — antennæ three-segmented; Philopteridæ, inhabiting birds only, — five-segmented antennæ. The suborder Amblycera is also subdivided into two families, viz. Gyropidæ, inhabiting mammals only; and Liotheidæ, inhabiting birds only. The families may be distinguished by the tarsal claws, which are distinctly two in number in the latter case and modified into clasping organs in the former, one of the claws being reduced.

Fig. 48. — Biting louse of the Angora goat, *Trichodectes hermsi*. × 22.

Species of Trichodectidæ. — Only a few of the commoner species need be considered here. The species belonging to this family are all small in size and belong to the genus Trichodectes. *Trichodectes latus* Nitzsch (Fig. 46) is the biting louse of the *dog*, most numerous on puppies. It is a broad short species about 1 mm. long, and more than half as wide. *Trichodectes subrostratus* Nitzsch of the cat is about the same length as *T. latus*, is not so broad and has a longer, more pointed head. *Trichodectes scalaris* Nitzsch infests cattle. The distinct ladder-like markings (Fig. 47) of the abdomen (present also in a few other species though less pronounced) gives rise to the specific name. *Trichodectes parumpilosus* Piaget is one of the biting lice of the horse, mule and ass. Osborn[1] describes this form, viz.: "the head is decidedly rounded in front, the antennæ inserted well back, so that the head forms a full semicircle in front of the base of the antennæ. The abdomen is more slender and tapering than in *scalaris*. . . . The color is much as in the allied species, the head, thorax and legs being a bright reddish brown, or chestnut, and the abdomen of a dusky yellowish color, with about eight transverse dusky bands occupying the central or anterior portions of the segments and extending from the middle line a little more than halfway to the margin. They are hardly as conspicuous as in *scalaris*." *Trichodectes climax* Nitzsch is fairly common on goats, *Trichodectes hermsi* Kellogg

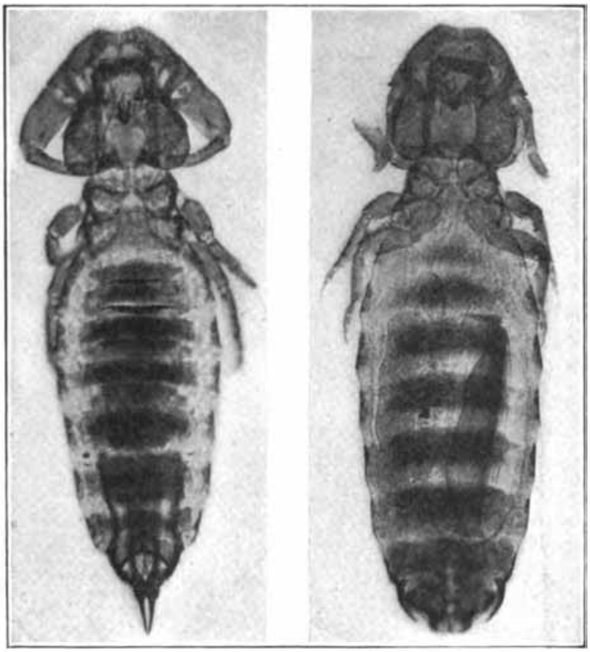


Fig. 49. — A biting louse of deer, *Trichodectes tibialis*; male, left; female, right. × 31.

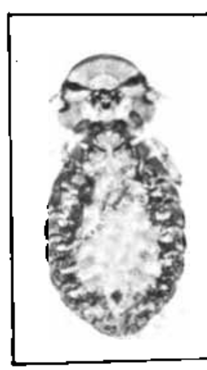


Fig. 50. — A hen louse, *Goniocotes abdominalis*. × 10.

[1] Osborn, Herbert, 1896. Insects Affecting Domestic Animals. U. S. Dept. of Agr., Division of Entomology, Bull. No. 5, N.S. 302 pp.

(Fig. 48) is abundant on the Angora goat, and *Trichodectes tibialis* Piaget (Fig. 49) is exceedingly abundant on deer.

Species of Philopteridæ. — Infesting chickens the following members of this family may be considered: *Goniocotes hologaster* Nitzsch, about 1 mm. in length, has a squarish head with angulated temples; *Goniocotes abdominalis* Piaget (Fig. 50), about 3 mm. long, broad with head circular in front; *Lipeurus variabilis* Nitzsch, 2 mm. in length, a long, very slender whitish species. The margins of the body are black; the head is large, rounded, and the whole appearance sufficiently distinct from any other species infesting the chicken, so that there can be no difficulty in distinguishing it at a glance. *Lipeurus heterographus* Nitzsch is said to differ from the above in having the "head rather narrowed in front instead of inflated, and the body is much stouter." This species has been taken by Osborn from chickens at Ames, Iowa.

FIG. 51. — A turkey louse, *Goniodes stylifer*. × 14.

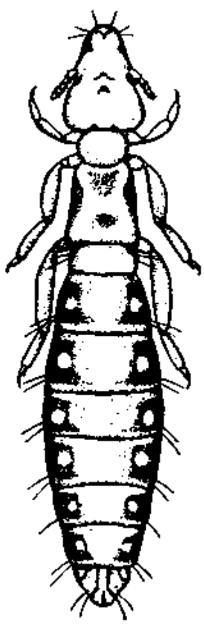


FIG. 52. — A duck louse, *Lipeurus squalidus*. (Redrawn after Osborn.) × 19.

Turkeys are commonly infested with the large (3 mm. long) *Goniodes stylifer* Nitzsch (Fig. 51), which has the posterior angles of the head extended backward into long projections or stylets terminating in bristles. Another louse found on turkeys is *Lipeurus polytrapezius* Nitzsch, like all members of this species, long and slender, 3 to 3½ mm.

Ducks and geese harbor a rather small-sized species of louse, *Docophorus icterodes* Nitzsch (1 mm.), "with head curiously expanded and rounded in front, darkish red head and thorax with darker bands, and a white region in the middle of the abdomen." — Kellogg.[1] Another common species infesting ducks and geese is *Lipeurus squalidus* Nitzsch (Fig. 52), which, according to Osborn, "is about 4 mm. in

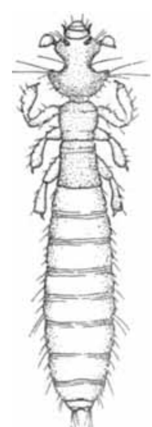


FIG. 53. — A biting louse of the guinea pig, *Gyropus gracilis*. (Redrawn after Osborn.) × 35.

[1] Kellogg, Vernon L., 1905. American Insects. vii + 674 pp. Henry Holt & Company.

length, elongate in form, and of a light yellowish color, with dark border to the head, thorax and abdomen. On the latter this border is broken into a series of quadrate patches corresponding with the segments."

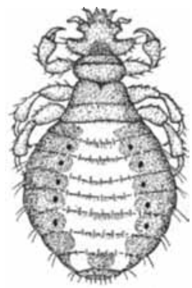


FIG. 54. — A biting louse of the guinea pig, *Gyropus ovalis*. (Redrawn after Osborn.) × 35.

Pigeons are affected by several species of biting lice, of which *Goniocotes compar* Nitzsch is quite common. It is about 1 mm. in length, described as follows: "The head is rounded in front, narrower between the antennæ, broadest near the posterior margin. The thorax is narrower, the abdomen in the male broadest near the posterior end and squarish behind, in the female more regular and broadest near the middle. It is whitish, with a rather broad brownish margin, from which prolongations extend inward upon the sutures." Another species said to be common on pigeons is *Goniodes damicornis* Nitzsch, length 2 mm.; in color it is brown. *Lipeurus baculus* Nitzsch is a very common form; it is about 2 mm. in length and exceedingly slender in conformance with the generic character. While the abdomen of this species is dark, the head and thorax are reddish brown in color.

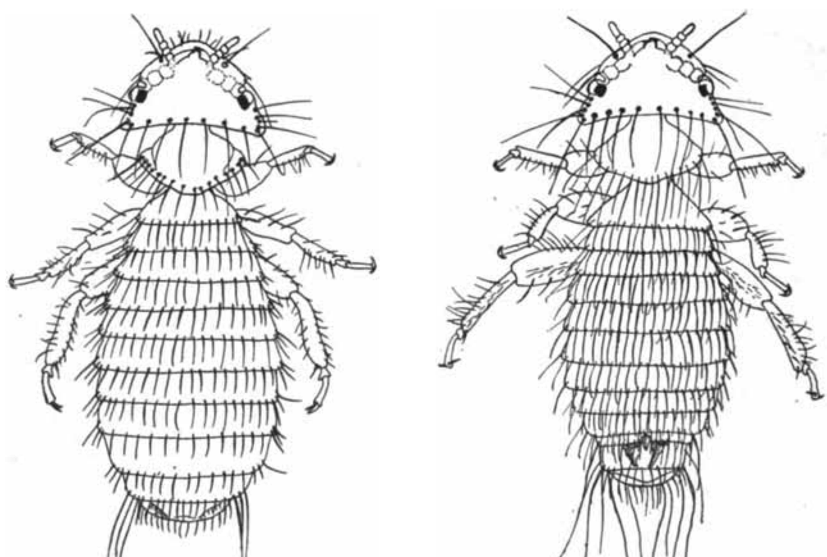


FIG. 55. — The common hen louse, *Menopon pallidum*. Male, left; female, right. × 33.

The commoner lice of the swan are *Docophorus cygni* Denny, about 1 mm. in length; "in color the head, thorax and legs are bright reddish brown while the abdomen is white in the center and dark brown at the sides, the brown occupying hard plate-like portions at the side of each segment;" and the extremely large and common *Ornithobius bucephalus* Piaget (4 mm. long). The latter is conspicuous because of its size, although the body is white and quite transparent.

Family Gyropidæ. — The members of this family are restricted to mammals. The genus Gyropus is a typical representative, of which *G. gracilis* Nitzsch (Fig. 53), a long slender form, is easily distinguishable from *G. ovalis* Nitzsch (Fig. 54) by comparing the figures; both species are found on the guinea pig.

Family Liotheidæ. — The commonest representative of this family is the widely known chicken louse, *Menopon pallidum* Nitzsch (Fig. 55). This species is the most prevalent of all the hen lice, is an active runner, light yellow in color and about 1½ to 2 mm. in length. Another member of this family, also infesting chickens, is *Menopon biseriatum* Piaget (Fig. 56), a somewhat larger species, and considerably less common. The head and anus of young chicks and turkeys seem to be frequently attacked by this species. *Trinoton luridum* Nitzsch of ducks is a large species measuring 4 to 5 mm. in length. *Trinoton lituratum* Nitzsch of the goose is smaller than the former, considerably lighter and without the dark markings.

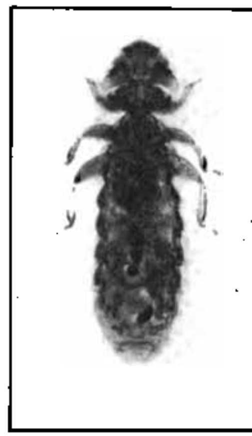


FIG. 56. — The head louse (*Menopon biseriatum*) of young fowls. × 16.

To Control Poultry Lice. — The very fact that poultry bathe in dust whenever available indicates a potent means of controlling the bird lice. In the erection of a modern poultry house the dust bath should be carefully provided for. Special boxes, broad and deep enough so that there will be room for several birds at a time, should be partly filled with fine road dust or ashes with the addition of a quantity of tobacco dust in the proportion of about six parts of the former to one of the latter. It is quite desirable to add a few handfuls of sulphur. The finer the dust the better, since the principle on which its use is based is that of suffocation, *i.e.* the dust particles enter and clog up the breathing pores of the lice. It is quite probable that the agitation caused by the dust and the "wallowing" of the bird dislodges many of the lice and they are lost in the shuffle. A very good louse powder for dusting birds by hand is prepared by mixing gasoline, 3 parts, and carbolic acid (about 90 per cent pure), 1 part, and stir into this mixture enough plaster of paris to take up the moisture. When preparing this mixture, it must be borne in mind that the gasoline is highly inflammable and that the carbolic acid is poisonous and injurious to the skin. Pyrethrum powder or buhach (fresh) applied to the hen directly by means of a duster is also a good remedy. A small handful of naphthaline flakes in each nest is very useful. Dipping chickens in a 2 per cent solution of chlorine is recommended by some.

The biting lice of mammals may be combated as described below for the Pediculids.

B. The Sucking Lice

Order Hemiptera, Suborder Parasita. Family Pediculidæ

Characterization. — With the characteristics of the biting lice well in mind there will be little difficulty in recognizing the sucking lice. The members of this group are suctorial, blood sucking, and restricted to mammals. The proboscis consists of a long fleshy extensile tube inclosing three slender stylets. The mouth parts are of the Hemipteron type except that the proboscis is not jointed. All the species are wingless, body compressed, antennæ five jointed, and tarsi are provided with strong claws adapted to hold the parasite firmly to the hairs of its host.

Pediculosis. — An infestation of lice is ordinarily termed *Pediculosis*, whether it involves man or beast; the term *Phthiriasis* denotes infestation by the pubic louse in particular. Pediculosis in animals may be indicated by the tendency to scratch and an effort to relieve the irritation by rubbing on rough objects, such as fences, posts, etc. These symptoms may, of course, indicate the presence of fleas or itch mites, but lousy animals usually have a rough, bristly coat, the eyes being "wild" in appearance, the body often emaciated.

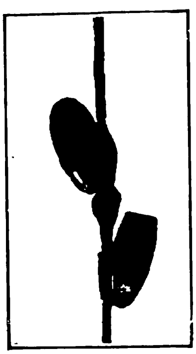


Fig. 57. — Nits or eggs of a sucking louse attached to the hair of the host. One of the eggs has hatched. × 10.

Life History. — The barrel-shaped eggs or "nits" are deposited on the hairs of the host (Fig. 57) and are glued fast by means of a sticky secretion. The period of incubation covers commonly from five to six days, the young insect on emerging having the general appearance of the adult except for size. Maturity is reached in most cases in from three to four weeks, which accounts for the rapid multiplication of these parasites. The dissemination of lice from one host to another is brought about by close association or by the indiscriminate use of toilet articles, clothing, currycombs, combs, brushes, etc.

Systematic. — All species of sucking lice which inhabit domesticated mammals belong to the genus Hæmatopinus. As is true in other genera, the legs are short and thick; in consequence their movements are very sluggish, and migration from host to host is not easily accomplished, except in certain species, such as the body lice of man, which are rather active. The genus Pediculus is restricted to man and the anthropoid apes. There is comparatively little structural difference between its members. The genus Phthirius is readily distinguishable from all other genera by its distinctly crablike appearance, broad body and strong clasping appendages.

Species affecting Man. — The three species of Pediculids infesting man are cosmopolitan and objects of great antiquity. The head louse, *Pediculus capitis* DeG. (Fig. 58), is about 3 mm. in length in the female and about 2 mm. in the male, varying from a light leaden color to nearly black. This difference in color is said to correspond to the color of the human host, also with the color of the hair in Caucasians. Murray[1] says, "Those of the West African and Australian are nearly black; those of the Hindu, dark and smoky; those of the Africander and Hottentot, orange; those of the Chinese and Japanese, yellowish brown; of the Indians of the Andes, dark brown; of the Digger Indians of California, dusky olive, and those of the North American Indian near the Eskimo, paler approaching to the light color of the parasites of the European." The eggs of the head louse are quite conspicuous, pear-shaped objects, usually attached near the base of the hair at the neck and back of the ears. Fifty is given by some writers as the number of eggs deposited by the female, and the great rapidity of reproduction becomes evident when it is known that the young female requires only about three weeks to reach maturity. In bad cases of pediculosis the hair of the head may literally become a mass of nits and parasites.

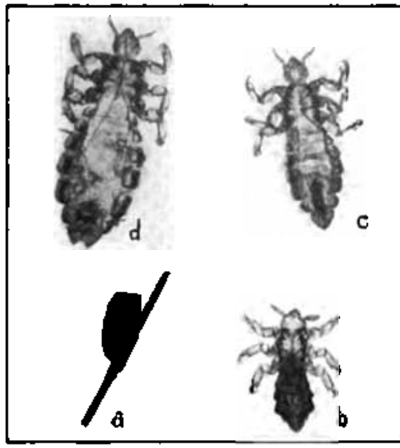


FIG. 58. — Life history of the human head louse, *Pediculus capitis*. *a*. egg; *b*. larva; *c*. male; *d*. female. × 10.

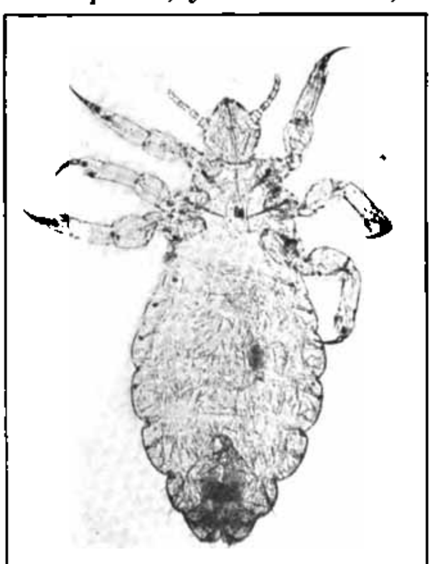


FIG. 59. — Human body louse, *Pediculus vestimenti*. × 15.

[1] Murray, Andrew, 1860. On the pediculi infesting the different races of man. Trans. Roy. Soc. Edinb., T. 22, p. 3, p. 567 (cited by Osborn).

Individuals who have had experience with the several forms of Pediculids say that the head louse does not produce the great discomfort that is caused by the body louse, *Pediculus vestimenti* Leach (Fig. 59). In size the body louse is somewhat larger than the head louse, ranging from 3 to 4 mm. in length. Size is not a good criterion for the separation of the two closely resembling species because of intergradation in the younger stages. However, by comparing the two species it will be seen that the antennæ of the body louse are relatively longer and more slender and that the abdomen is broadly attached to the thorax. This species infests the clothing of human beings, particularly that worn next to the body, where the eggs are deposited. Careful observations on the life history of this parasite were made by Warburton (see Nuttall [1]), who found that the female laid 124 eggs during the course of twenty-five days, and hatched in eight days under favorable conditions. The adult stage was reached on the thirteenth day after three molts, which occurred about every fourth day. Adults entered into copulation five days after the last ecdysis or molt. The adults reared by Warburton lived about three weeks after the final molt, and the "egg to egg" period was reckoned at about twenty-four days. Irritation is caused by sucking blood and by scratching with their claws while crawling about on the skin. The grayish color which is characteristic of this species gives rise to the significant term "gray-back." The "gray-back" is usually the unwelcome associate of camp laborers, soldiers and rangers, and is commonly looked upon as a part of the initiatory features of such life.

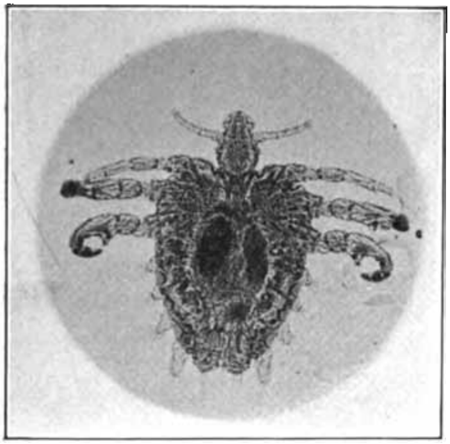


FIG. 60. — The pubic louse, *Phthirius inguinalis*. × 23.

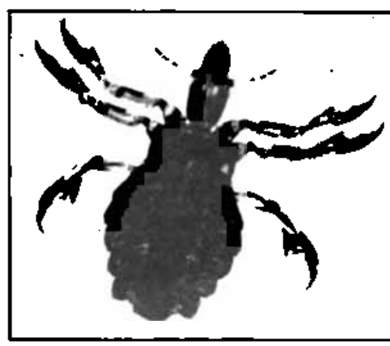


FIG. 61. — Hog louse, *Hæmatopinus (urius) suis*. × 7.

If there is any possibility of degree in the matter, the most disgusting of all lice infesting human beings is the pubic or crab louse,

[1] Nuttall, G. H. F., 1913. The Herter Lectures I. Spirochætosis. Parasitology, Vol. 5, No. 4, pp. 271–272.

Phthirius inguinalis Leach (Fig. 60), which infests the pubic region particularly and the armpits, rarely other parts. The ease with which this form is transmitted accounts for the astonishing abundance and frequent occurrence of these parasites on men in various stations in life. Its identity cannot be mistaken if the appended figure is taken into account. It measures from 1 to 1.5 mm. in length and is nearly as broad as long. The eggs, not usually more than a dozen per female, are attached to the coarse hairs of the region infested. The incubation period lasts from five to six days and full growth is reached in about three weeks.

FIG. 62. — The short-nosed ox louse, *Hæmatopinus eurysternus*. (Redrawn after Osborn.) ×22.

Species affecting Domesticated Animals. — The principal species of pediculi infesting the domesticated animals belong to the genus Hæmatopinus. Each of these species inhabits a specific host, so that, in all but accidental cases, the specific name may be known when the parasite is taken on its host, with only a good hand lens as an aid to identification. *Hæmatopinus suis* Linn. (Fig. 61) of the hog is the largest representative of the genus, measuring as much as 5 to 6 mm. in length. It is a cosmopolitan species, often infesting the host in great numbers. It seems evident, from general observations, that the presence of these parasites when numerous affects swine quite seriously. Next to cholera this louse is said to be the hog's worst enemy. The head of the hog louse is long, and together with the thorax and abdomen is provided with a conspicuous dark border. *H.* (*asini* Linn.) *macrocephalus* Burm. of the horse is smaller (2.5 to 3 mm.), otherwise similar in form, except that the head is relatively longer and more robust. Cattle may be infested with one of two species, *H. eurysternus* Nitzsch, the short-nosed ox louse, or *H. vituli* Linn., the long-nosed ox louse. The former is somewhat the larger (1.5 mm. to 2 mm.), broader in proportion and short nosed (Figs. 62–63). The long-nosed ox louse is said to infest the neck and shoulders in preference to other parts. *H. pedalis* Osb. is the sheep foot louse, said by Osborn to occur only on the legs and feet below where the long wool is found, and particularly in the region of the dew claws, where the eggs appear to be most commonly deposited. In shape it resembles the long-nosed ox louse, but is more slender.

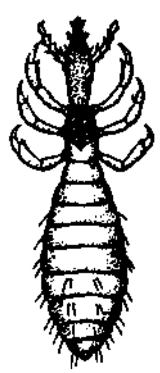


FIG. 63. — The long-nosed ox louse, *Hæmatopinus vituli*. (Redrawn after Osborn.) ×30.

Although other observers have found the sucking dog louse, *H. piliferus* Burm., less common than the biting dog louse, the writer has found this species quite as common in California if not relatively more abundant. The adults are about 2 mm. in length; the antennæ are short and heavy, as are the legs, while the hairy abdomen is oval and usually apparently swollen.

Other Species of Hæmatopinus. — Experiments with rodent lice as transmitters of trypanosomes have brought several of these species into prominence, notably *Hæmatopinus spinulosus* Burm. of the rat. It is light yellow in color, the head projecting very little in front of the antennæ, and the thorax is very short. *H. acanthopus* Burm. is the sucking louse of the field mouse, while *H. hesperomydis* Osb. occurs on the white-footed mouse. The ground squirrel harbors a species known as *H. suturalis* Osb., described by Osborn, viz. "This species is particularly well marked by the general form of the body and especially by the conspicuous transverse suture back of the antennæ. It differs further from most of the species in the genus in having both the anterior and middle legs slender and of nearly the same size, while the posterior legs alone are especially modified as clasping organs."

Relation to Disease. — Lousiness may correctly be designated as a disease and is technically termed *Pediculosis* or *Phthiriasis*. This applies equally well to either the biting or sucking lice. While the presence of lice on the body of an animal may not result in serious consequences, nor even in much discomfort, an abundance of these parasites naturally results in a weakened condition, predisposing the host to other diseases through loss of blood (when infested with sucking lice) and general irritation resulting in poor digestion. Intense irritation, *pruritus*, on the trunk of the body in human beings is often the result of body lice. Furthermore, it is quite certain that infection may be transmitted from animal to animal (of the same species) by lice, either upon feet and mouth parts, as the bee carries pollen, *e.g. impetigo*, or within their bodies, as explained under *spirochætosis*.

Impetigo. — In the human such diseases as *Impetigo* and *Favus* may be transmitted by the pediculi. Tropical impetigo (*Pemphigus contagiosus*) is said to be caused by *Diplococcus pemphigi contagiosi* Wherry, while favus is traceable to a fungus variously classified, probably best known as *Achorion schoenleini*. The following experiments cited from Nuttall,[1] bear evidence to the transmission of impetigo: "Dewevre (1892) claims that pediculi disseminate impetigo. He removed ten pediculi from a child suffering from impetigo and placed them on a healthy infant, which a few days later developed impetigo. The experiment was repeated several times with the same results. In a second series of experiments, he took scrapings from under the nails of children that had impetigo, and placing them on artificially scratched places, reproduced the disease. Lastly he took pediculi from a child that was not affected with impetigo and placed them on a child that had the disease; removing them after twenty minutes, he replaced them on a healthy child. The latter acquired the disease, as did fifty per cent of the children so experimented with. He claims the specific microörganism adheres to the front legs especially, also to the hairs of the insect, and the latter carries them as bees do pollen. In the last set of experiments, he only

[1] Nuttall, G. H. F., 1899 (*loc. cit.*).

allowed the pediculi to remain half an hour on the healthy head, but this was sufficient to produce infection." The above typical example also illustrates the methods used to secure the experimental evidence of transmission.

Spirochætosis. — An infection of spirochætes is known as *spirochætosis*. The spirochætæ are protozoa belonging to the class Zoömastigophora (Flagellata), order Spirochætida. They consist of undulated filamentous bodies, in some of which there is said to be present a narrow membrane extending from end to end of the body. In the genus Treponema, *e.g. Treponema pallidum* Schaudinn (Fig. 64) of syphilis, the membrane is absent and the body is strongly spiral; in the genus Spirochæta, *e.g. Spirochæta novyi* (Shellack), the body is wavy or undulatory (Fig. 65).

Fig. 64. — Smear preparation showing *Treponema pallidum* of syphilis. (Greatly enlarged.)

Both man and beast are affected by *Spirochætosis*, but in the former the term *relapsing fever* is ordinarily applied. The relapsing fevers are characterized by fevers sudden in appearance and rather sudden in subsidence, with relapses at irregular and indefinite intervals. The mortality is given at about 5 per cent. Relapsing fever is most likely to be confused with malaria but for the characteristics above mentioned and the presence of spirochætes in greater or less number in the blood of the patient.

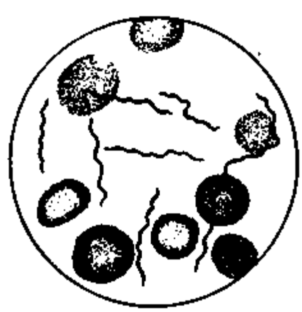


Fig. 65. — *Spirochæta novyi* in a blood smear. (Greatly enlarged.)

The African relapsing fever, traceable to *Spirochæta duttoni* (Novy and Knapp), is transmitted by ticks; while the European form, traceable to *Spirochæta recurrentis* (Lebert), the American form (*Spirochæta novyi* Shellack) and the Indian form (*Spirochæta carteri* Mackie) are transmitted by the pediculi, as later described.

The first important evidence to the effect that lice may be concerned in the transmission of relapsing fever was advanced by Mackie[1] in India in 1907, who records an outbreak of the disease among school children, in which 137 out of 170 boys and 35 out of 114 girls were attacked. Twenty-four per cent of the lice removed from the boys contained spirochætes, while only 3 per cent of the lice removed from the girls were infected. As the parasites increased in abundance among the girls, so also did the epidemic increase,

[1] Mackie, F. P., 1907. The part played by *Pediculus corporis* in the transmission of relapsing fever. British Med. Journ. 1907, p. 1706.

and conversely as the parasites became less abundant among the boys, so also did the epidemic decrease. The spirochætes were observed to multiply in the intestine of the lice and were found to be present in the ovaries, testes and Malpighian tubules. Mackie concluded that infection might be spread by the lice by regurgitating the spirochætes into the wound produced by the bite.

Later (1912) Nicolle, Blaizot and Conseil[1] failed to transmit the spirochætes through the bites of infected lice, and found that the only reliable successful experiments involved the injection or subcutaneous inoculation of an extract of infected lice.

Based on experiments in which men and monkeys were exposed to hundreds of bites, Nicolle and his colleagues came to the conclusion that transmission is brought about by the introduction of spirochætes received under the finger nails and on the finger tips from crushed parasites, which are inoculated into excoriated skin in scratching. They also found that the spirochætes disappear and later reappear, only a few remaining in the insect's intestine up to five or six hours after infection, and none after twenty-four hours, but reappear in the insect in from eight to twelve days and are then present in the general body cavity, none being found in the alimentary canal. It was also found that the spirochætes are transmitted to the offspring of infected lice.

The incubation period in the human is said to be from seven to ten days.

Typhus Fever. — Typhus fever, known also as tarbardillo (Mexico), Brill's disease (United States), jail fever or war fever, is a disease of ancient origin and wide distribution. The disease is characterized by a high fever, backache, headache, bronchial disturbances, congested face (designated also as a " besotted expression "), brick-red mottled eruption which later spreads, becoming brownish irregular blotches. This spotting led to the belief that tarbardillo of Mexico was identical with spotted fever of Montana, a fact proved untrue by Ricketts, who lost his life by typhus fever during the course of his investigation. Experiments and observations by Nicolle and Ricketts and Wilder[2] indicate that the bedbug and the flea are not instruments of transmission. That the body louse (*Pediculus vestimenti*) is the most important, if not sole agent, in the transmission of typhus fever has been proved by Nicolle et al.[3] (1909, working in Tunis) and Ricketts and Wilder[4]

[1] Nicolle, C. N., Blaizot, L., and Conseil, F., 1913. Ann. Inst. Pasteur, March 25, 1913, pp. 204–225.

[2] Ricketts, H. T., and Wilder, R. N., 1910. Further investigations regarding the etiology of tarbardillo, Mexican typhus fever. Journ. Amer. Med. Assoc., Vol. 55, No. 4, pp. 309–311.

[3] Nicolle, Charles, Comte, C., et Conseil, E., 1909. Transmission expérimentale du typhus exanthimatique par le pou du corps. Paris Acad. Sc. Comptes Rendus, T. 149, pp. 486–489.

[4] Rickets, H. T., and Wilder, R. M., 1910. The transmission of the typhus fever of Mexico (tarbardillo) by means of the louse (*Pediculus vestimenti*). Journ. Amer. Med. Assoc., Vol. 54, No. 16, pp. 1304–1307.

(1910, working in Mexico). The latter found that *Macacus rhesus* can be infected with tarbardillo (Mexican typhus) invariably by the injection of virulent blood from man taken on the eighth to tenth day of fever, that the monkey may pass through an attack of typhus so mild that it cannot be recognized clinically and that vaccination results. Typhus was transmitted to the monkey by the bite of the louse in two experiments, the lice in one instance deriving their infection from man and in another from the monkey. Another monkey was infected through the introduction of the feces and abdominal contents of infected lice into small incisions. The causative microörganism of typhus is claimed by Plotz to be a small Gram positive, pleomorphic bacillus.

The incubation period in the human is from ten to twelve days. The duration of the disease is said to be about twelve days in children, in which it is usually comparatively mild, to twenty-one to twenty-four days in adults. The mortality is said to range from 15 per cent to 30 per cent, but may be as high as 50 per cent to 75 per cent under war conditions.

Rat Trypanosomiasis. — A relatively common and apparently non-pathogenic protozoan parasite of the rat is *Trypanosoma lewisi* Kent. Various observers, among them Brumpt and Minchin and Thomson, have determined that this trypanosome is transmitted by the rat louse, *Hæmatopinus spinulosus*, in which host the protozoön undergoes certain developmental changes. Other insect hosts of the trypanosome are known, among them the rat flea, *Ceratophyllus fasciatus*.

Relation to Tæniasis. — *Dipylidium caninum* Linn. (*Tænia cucumerina*), the double-pored dog tapeworm, is a common parasite of the dog and is occasionally found in humans, especially children. It measures from ten to fourteen inches in length, has long seedlike proglottides and an armored scolex, and has as its larval host the biting dog louse, *Trichodectes latus*.[1] The larva or bladder worm, known as *Cysticercus trichodectes*, has been experimentally produced in the louse by placing ripe crushed proglottides of the tapeworm on the skin of a dog infested with lice.

As has already been explained, the biting lice subsist on epidermal scales, skin exudations and other matter on the skin of the animal. This habit makes it comparatively easy for the louse to become infected through eggs in the kennel in which the dog lies. The dog, on the other hand readily infects himself by devouring the lice which irritate his skin.

Persons, particularly children, while fondling louse-infested dogs may easily become infected by accidentally swallowing lice which contain bladder worms. This is more readily accomplished if the person is eating at the time.

How Lice are Disseminated. — The most effective means for the distribution of lice on humans is the indiscriminate use of toilet articles, garments and bedding; also close association. The mere presence of lice

[1] Occurs also in the dog flea, *Ctenocephalus canis*, and in the human flea, *Pulex irritans*.

does not invariably indicate uncleanly habits, but the continued presence of these parasites is inexcusable. Cases have come under the observation of the writer in which several members of a highly respectable family were sadly infested with the head louse, to their great dismay. Members of this family were greatly alarmed, believing themselves disgraced for all time. The infestation was thus explained. It was found that a maid employed by the family had previously been engaged by another family whose children became infested in school, as may happen. In caring for the children the maid in turn became infested and shortly thereafter sought another position, which was found with the family in question. By indiscreet use of combs and brushes a general infestation was inevitable.

Domesticated animals may have lice communicated to them by close association, especially in the winter time, and by infected curry combs, blankets and similar articles, also by rubbing on stalls, fences, etc. against which infested animals have previously rubbed themselves.

Treatment. — Personal cleanliness is by far the best method to prevent lice from gaining a foothold; however, the exception has already been indicated. The mere use of water is ineffective in destroying vermin present in the hair, and the " nits " are even more difficult to destroy. In the case of the body louse, a clean body would not prevent reinfestation if the same underclothing are put on in the absence of a change, which often occurs where men are necessarily far removed from civilization or are under accidental conditions.

To free the head of lice a fine-tooth comb dipped in any hair pomade containing oil may be used. Dipping the comb in ordinary kerosene before applying to the head is a method frequently employed with good results. Several families in which this method has been followed under the writer's observation were completely freed of the parasites in that manner, with at least no apparent injury to the hair, an objection sometimes raised. The oil coming in contact with the lice kills them, but the eggs or nits cannot be destroyed so well; therefore the combing process must be repeated three times at intervals of one week in order to destroy the newly hatched lice and thus prevent fresh propagation. Care should be exercised in removing the parasites, so that further dissemination does not occur. A good method is to use a black oilcloth or slate upon which the combings are placed and the parasites certainly destroyed by an application of kerosene. The whitish parasites can readily be seen on the black background and none need escape. Washing the head in a 2 per cent solution of *creolin* is also effective if repeated as above. Winding the head in long towels wet with tincture of larkspur (Delphinium), 10 per cent, is strongly recommended by many.

The heads of children with long hair may be treated successfully in the following manner, as described by Whitfield in the *Lancet* (Dec. 14, 1912). The child is placed on its back in a bed, with the head hanging over the edge, so that the hair falls in a basin resting on a chair. The solution to be used (the author recommends Phenol 12 grams and water 500 grams) is poured over the hair and carefully washed back and forth for a period of ten minutes until the hair is well soaked, particularly back of the ears and the nape of the neck. Afterwards the hair is drained, not wrung out, however, and is then put up with a towel or flannel cloth in turban fashion. After an hour the hair may be washed out or simply left to dry, when it will be found that all the pediculi as well as the ova have been destroyed.

Body lice can only be controlled by treating the clothing and bedding of the person infested. A favorable abode is provided by the folds and hems of undergarments where the eggs are deposited and where a lively existence is manifested. Consequently the necessity for a complete stripping off of all wearing apparel to the smallest detail becomes apparent. All garments should then be at once subjected to a baking, steaming or fumigating process; the undergarments may be boiled. Soaking all garments in gasoline or benzine is also recommended. It is suggested that this is the simplest process as it kills all the adults at once, and if it can be repeated at short intervals, the clothing can be worn in the period between treatments. The extreme irritation caused by body lice may be relieved by the application of a lotion of one half ounce of borax to a pint of water.

In dealing with lice under typhus fever conditions the greatest care must be exercised owing to the minuteness of the parasites and the great danger from infection. The patient must be completely stripped in a special room, placing his garments at once in a vessel and covering them immediately with benzine or gasoline. The face and head must be shaved and the hair burned at once. All instruments must be carefully sterilized.

The liberal use of kerosene on floors and beneath cots is strongly urged. Rubbing the body with kerosene acts as a good preventive; the use of flowers of sulphur has also been recommended.

The pubic louse, easily disseminated, is also easily eradicated because of its local occurrence in both the adult stage and the egg. However, notwithstanding the ease of locating them, they are extremely tenacious, and repeated applications of the remedy must be resorted to. Mercurial ointment (blue ointment) applied as a salve to the parts affected is commonly used. The proportions recommended are two parts of mercurial ointment and one part petrolatum. The use of mercurial ointment directly after a bath may produce bad results, and furthermore the salve is not to be strongly rubbed in. Tincture of larkspur (Delphinium) 10 per cent is recommended or also 10 per cent solution of fishberry and alcohol or just plain kerosene. All treatments must be repeated at least three times at intervals of about one week in order to destroy larvæ newly emerging from eggs not attacked by the chemicals. An application of vinegar makes the eggs more susceptible to the treatment.

Control on Animals. — When domesticated animals are lousy, their quarters must be thoroughly cleaned and disinfected, together with currycombs and similar articles. The latter may be dipped in kerosene or crude oil. Cattle, sheep and hogs may be dipped, sprayed or hand dressed with tobacco decoctions. Owing to differences in nicotine content tobacco dips must be used as specifically directed. Creolin, 2 per cent for dogs, cats, monkeys, and 4 per cent for hogs is useful; kerosene emulsion (10 per cent for hogs), tincture of larkspur 10 per cent, or other remedies such as Kreso, Chloronaphtholeum, etc., as specifically directed. Horses, of course, should not be dipped, but may be treated with creolin 2 per cent or kerosene emulsion 10 per cent, or other remedies above mentioned by local applications with rub rags or currycomb. Kerosene in any form should not be applied to animals in the hot sunshine. All treatments for lice must be repeated at least three times at intervals of about a week to ten days in order to destroy the young lice emerging from eggs not destroyed by chemicals. It is advisable to add creolin to hog wallows from time to time, a measure which proves very useful in keeping the animals comparatively free from lice.

Fumigation for lice is seldom practiced, because of the special equipment necessary and time required for the operation. Osborn has successfully used fumigants in the control of the short-nosed ox louse. In his experiments the animal was placed in a tight box stall, one end having a close-fitting door to admit the largest animal to be treated, the opposite end a stanchion in which the animal is fastened. An opening at the stanchion end of the stall is made for the animal's head to protrude, and is surrounded by a sack-like covering open at both ends, the inner end nailed to the opening and the other made to fit tightly around the head just in front of the horns, thus exposing the eyes and nose to the air. The fumigating substance is introduced into the stall through an opening at the side near the bottom. Osborn used tobacco, which was placed on a wire screen over a tin trough containing alcohol. He states that it should, however, be burned with coals or by using a small quantity of kerosene. One or two ounces of tobacco and an exposure of twenty to thirty minutes was found effective. He also adds that pyrethrum might even be better than tobacco. The time of exposure necessary will vary.

CHAPTER VIII

BEDBUGS AND CONE-NOSES

A. The Bedbugs

Order Hemiptera, Family Cimicidæ

Characterization. — Members of the family Cimicidæ (Acanthiidæ) are extremely flattened in form, fitted to crawl in narrow crevices. As adults they are reddish brown in color and wingless but for the merest pads and are possessed of a characteristic pungent odor which when once noted will be easily recognized thereafter. The mouth parts of this family are of the typical Hemipteron type; they are three-segmented and inclose long slender stylets. The Aradidæ, or flat bugs, in their younger stages are often mistaken for Cimicidæ. The bedbugs are normally intermittent parasites, but may undergo long periods of starvation, at least one year.

Systematic. — The family Cimicidæ belongs to the Order Hemiptera, which is subdivided into three divisions or suborders: (1) **Heteroptera**, in which the forward pair of wings, when present, are thick and leathery (coriaceous) proximally, and membranous distally; the mouth parts are free and the long axis of the head forms a straight line with the body, *e.g.* Cone-noses (Ruduviidæ), Squash bugs (Coreidæ) and Bedbugs (Cimicidæ); (2) **Homoptera**, in which the wing covers, when present, are membranous throughout and the mouth parts may or may not be fused to the thorax, while the long axis of the head forms a right angle with the body, *e.g.* Cicadas (Cicadidæ), Leaf hoppers (Membracidæ) and Plant lice (Aphididæ); (3) **Parasita**, which includes the sucking lice (Pediculidæ) already considered.

The three principal genera of the family Cimicidæ [1] are (1) Cimex, in which the rostrum is short, reaching about to the anterior coxæ; body covered with short hairs, only the lateral sides of pronotum and elytra fringed with longer hairs; antennæ with the third and fourth joints very much thinner than the first and second and capillary; (2) Œciacus, in which the body is clothed with long silky hairs; third and fourth joints of the antennæ only a little thinner than the first and second and filiform; (3) Hæmatosiphon, in which the rostrum is long, reaching to the posterior coxæ.

The genus Cimex, among others, is represented by the common bed-

[1] Horvath, G., 1912. Revision of the American Cimicidæ. Annales Musei Nationalis Hungarici, Vol. X, pp. 257–262.

bug, *C. lectularius* Linn.; it has the body covered with short hairs; the second joint of the antennæ is shorter than the third. *C. pilosellus* Horv. is a parasite of bats (*C. pipistrelli* Jenyns is European); it has the body covered with longer hairs, and the second and third antennal joints equal in length. *C. hemipterus* Fabr.(= *C. rotundatus* Patton = *C. macrocephalus* Kirk.) is a parasite of man and poultry as well; it occurs in Africa, Asia, South America and Jamaica. In this species the lateral sides of the pronotum are dilated, not reflexed, fringed with less dense and nearly straight hairs, elytra with the apical margin distinctly rounded (Horvath).

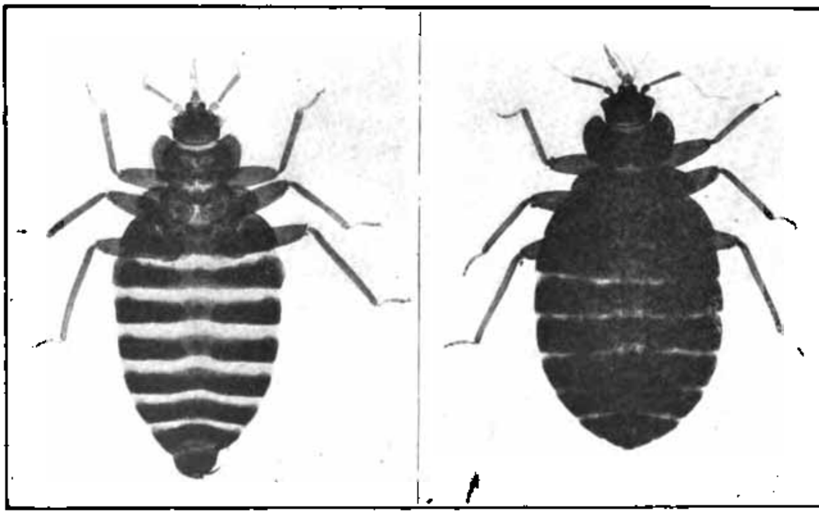


FIG. 66.—The common bedbug, *Cimex lectularius*. Male, left; female, right. Also shows piercing stylets exposed. × 10.

The genus Œciacus is represented by the European barn swallow bag, *O. hirundinus* Jenyns, and *O. vicarius* Horv., the corresponding American species.

Hæmatosiphon inodorus Duges is the only known species of this genus, and infests poultry in Mexico and southwestern United States. The generic characters already referred to serve to distinguish this species.

The Common Bedbug.—The common adult bedbug, *Cimex lectularius* Linn. (Fig. 66), measures from 4 to 5 mm. in length, 3 mm. in breadth, is obovate in form and much flattened. The adult is reddish brown in color, though the young insects are yellowish white. Among the local names applied to these insects are "chinches," "chintzes," "red coats," "mahogany flats," "wall louse," "bedbugs" or simply "bugs."

Bedbugs, like the lice, have been the constant companions of man for centuries, — the earliest writings on Natural History (Pliny and Aristotle) make mention of them.

Habits and Life History. — Bedbugs are nocturnal in their feeding habits, hiding in crevices during the day. At night they are very active, crawling out of their hiding places often to travel considerable distances to attack their victims. This is especially true where iron bedsteads are used which do not provide convenient hiding places for the bugs. Ordinarily where the old-fashioned wooden bedsteads are used the bugs stay closer to their point of attack. They are gregarious, hence often great assemblages may be found in some convenient crevice. In such situations the eggs are usually deposited.

The females deposit from 75 to 200 rather large yellowish white eggs easily visible to the naked eye. As in many Hemiptera, often only very few eggs are deposited at a time and oviposition occurs at intervals during a period of from two to three months. The period of oviposition is apparently limited to the spring and summer months, notwithstanding the fact that the insects are commonly favored by warm rooms during the winter. The eggs are whitish in color and distinctly reticulated. The young, which have the general form of the adults (therefore simple in their metamorphosis), hatch in from five to twelve days, influenced by temperature, however, as is their later growth. Thus the results of experiments and observations of writers differ greatly with regard to the life history. The time required for development from the egg to maturity is given at from forty-five days to eleven months and there may be two or more generations. Ordinarily eight to ten weeks are required to reach maturity. The presence or absence of food influences this period greatly. Marlatt[1] has shown that bedbugs molt five times and that the minute wing pads make their appearance with the last molt. He also found that ordinarily but one meal is taken between each molt and one before egg deposition and that an average period of eight days is required between moltings.

Methods of Distribution. — Bedbugs, like lice or any other organism, cannot originate spontaneously in filth as is believed by many; they must be introduced in some manner, either in the form of eggs, young or adults. Thus the introduction of one impregnated female might furnish the nucleus for a well-developed colony of bedbugs inside of a few months. Hence the best regulated household is not exempt from invasion, though cleanliness is the best preventive against the multiplication of any household pest.

Public conveyances are commonly means for the dissemination of bedbugs. As Smith[2] has well said, "I have seen them in railroad cars, trolleys, boats, omnibuses and carriages, and have noted them

[1] Marlatt, C. L., 1902. The Bedbug. Circ. No. 47, Second Series, U. S. Dept. of Agric., Div. of Entomology.

[2] Smith, John B., 1909. Our Insect Friends and Enemies. J. B. Lippincott Co., 314 pp.

crawling on the clothing of well-dressed fellow passengers who probably did not bring them in." Furthermore, migration from house to house by way of water pipes, walls and the like is not at all unlikely when infested houses are vacated and the food supply is cut off. They are also easily carried in clothing, traveling bags, suit cases, etc.

Bedbug Bites. — Persons "bitten" by bedbugs are differently affected; in some the bite produces marked swellings and considerable irritation, while in others not the slightest inconvenience is caused. (The same condition is found in the case of flea bites and mosquito bites.) The bite, so called, of the bedbug is produced by puncturing organs of the Hemipteron type already described. It is probable that the pierce of these stylets, unattended by contamination or specific poisons, would produce little pain. The local irritation and swelling is unquestionably produced by a specific poison of alkaline reaction secreted by the salivary glands and introduced in the act of feeding.

The fact that the bedbug is obliged to feed at least five different times either upon the same or a different host, — the latter being the case most probably in rooming houses, hotels and crowded dwellings, — leads to the question of disease transmission.

Disease Transmission. — In consequence of statements made by a number of authors that the bedbug is capable of transmitting plague and other septicæmic infections, Nuttall[1] carried on a series of experiments with these insects. Mice were used in these experiments because they are very susceptible to the affections in question. He allowed the bugs to bite mice which had just died or were dying of anthrax, plague and mouse-septicæmia and then transferred them to healthy mice. Nuttall's experiments with anthrax are particularly instructive. Mice inoculated with anthrax died in from eighteen to twenty-four hours, after which they were placed in glass-covered dishes and hungry bugs introduced. As soon as the bugs had sucked a little blood they were removed to test tubes by means of a small camel's-hair brush and transferred to a shaved spot on healthy mice, by inverting the tubes. Eight mice bitten by 124 infected bugs all remained healthy. Variations of this experiment gave similar results. It was found that the anthrax bacilli die in the stomach of the insect in forty-eight to ninety-six hours at 13° to 17° C. and in twenty-four to forty-eight hours at 37° C., and that the feces from the bugs contained living bacilli during the first twenty-four hours after feeding. In view of these experiments it may be concluded that infection through the bite of a bedbug either does not occur or is exceptional. That infection might occur if recently infected bugs were crushed while feeding and the punctured parts scratched is to be expected.

Kala Azar. — Kala azar or dumdum fever is a highly fatal protozoal disease of India, having in many respects some similarity to malignant ague, but does not respond to quinine. The causative organism,

[1] Nuttall, 1899 (*loc. cit.*).

Leishmania donovani (Ross), is found in closely packed masses in the cells of the spleen and other viscera. These organisms, also known as *Leishman-Donovan bodies*, are said to be a non-flagellate stage which develops a flagellate stage in some other host. They are "approximately circular or oval, 2.5 to 3.5 micra in diameter, clearly outlined, and appear to possess a distinct cuticle, as they retain their shape and are rarely seen distorted in films. The two chromatin masses are characteristic, the large one staining slightly and the small one intensely with Romanowsky. The masses are usually situate opposite each other in the short axis of the parasite."

Observations made by Patton [1] show that flagellate forms develop in from five to eight days in bedbugs after feeding on kala azar patients. Much circumstantial evidence strongly implicates both the Indian bedbug *Cimex hemipterus* (*C. rotundatus* Patton) and the common *Cimex lectularius* as probable important transmitters of this disease.

Relapsing Fever (Spirochætosis). — The relapsing fevers traceable to *Spirochæta duttoni* (African form) and *Spirochæta recurrentis* (European form) are probably disseminated to some extent by the bedbug (*Cimex lectularius*), since it has been shown by Nuttall [2] that the spirochætes survive in the bodies of bugs for a period of six days at a temperature of 12° C., and a much shorter period (six hours) at 20–24° C. He, however, succeeded in transmitting the disease to a mouse, in only one instance, by transferring thirty-five bugs from an infected mouse to an uninfected mouse. The evidence at hand seems to indicate that the bedbug is relatively unimportant.

Control. — The habits of these parasites indicate in a measure the methods useful in their eradication in a given situation. The ease with which they secrete themselves in very narrow crevices provides safety against anything but very penetrating materials. Thus pyrethrum powder is only useful where the insects are quite exposed or within reach of a blower. The newer metal bedsteads are easily kept free from the bugs, while the old-fashioned wooden bedsteads are more difficult to handle; however, the writer has seen some very bad infestations entirely eliminated by the use of kerosene applied by means of a tail feather from a fowl. The more penetrating oils, such as gasoline and benzine which volatilize more readily, are to be recommended; however, greater *precaution against ignition must be exercised.*

A thorough infestation of bedbugs will require a more strenuous campaign, extending even to the removal of all loose wall paper under which the bugs may have found a hiding place. Where the infestation has reached such proportions as to include several rooms or even an entire building, the more rapid and effective fumigation methods are far preferable, requiring less labor and producing better results.

[1] Patton, W. S., 1907. Scient. Mem. of the Gov. of India. Nos. 27 and 31.
[2] Nuttall, G. F. H., 1913. The Herter Lectures. I. Spirochætosis. Parasitology, Vol. 5, No. 4, pp. 262–274.

Hydrocyanic acid gas is perhaps the most effective of fumigating agents, but the greatest care must be exercised in the process, since the gas is deadly to all forms of animal life and extremely penetrating. Rooms above apartments in which this gas is being applied should not be occupied during or immediately after the process. Sparrows have been known to drop from the eaves of houses in which cyanide fumigation was going on. However, with proper precautions very little danger is involved.

To prepare a room for cyanide fumigation, all wet or moist food-stuffs must be removed (dry materials such as flour, meal, bread, etc. need not be removed); if the house is occupied, *there must be no crevices leading from the room to be fumigated to occupied rooms.* It is best that the house should be vacated during the process, — this need be for only a period of five or six hours. Fumigation should not be undertaken when it is cold; a temperature of about 70° F. gives best results. If there is a fireplace in the room, this should be covered with a blanket or other covering. All crevices, such as occur around the doors and window sashes, keyholes, etc., must be tightly covered with strips of paper pasted in place with a very dilute flour paste, or as some have found, merely soaked in water. The cubic contents of the room must be estimated and sufficient ingredients provided to do the work. One ounce of potassium cyanide for every one hundred cubic feet of space is necessary. To generate the gas sulphuric acid and water must be used. The following proportions are needed for one hundred cubic feet of space: —

Potassium cyanide (98 %)	1 oz.
Sulphuric acid (about 66° Beaumé)	1 fluid oz.
Water	3 fluid oz.

or for 130 cubic feet of space: —

Sodium cyanide (129 %)	1 oz.
Sulphuric acid	1 fluid oz.
Water	2 fluid oz.

To proceed place the water (in proper proportion) in a heavy two to three gallon earthen jar placed on thick folds of paper to catch spattered liquid, then slowly add the sulphuric acid (water always first, then the acid), lastly drop a paper bag containing the cyanide into the liquid, holding same at arm's length, and *immediately* beat a hasty retreat, carefully closing the door. After the expiration of about five hours, open the windows from the outside and permit the room to "air" until the "peach kernel" odor has disappeared. The contents of the jar should be carefully disposed of.

In treating an entire building the operator must always begin at the top and work downward.

To fumigate with sulphur, a very efficient method to destroy bed-bugs and other vermin, flowers of sulphur or lump sulphur is used. The rooms are prepared as for hydrocyanic acid gas fumigation. All metal objects and fine, delicately tinted fabrics must be removed, if possible; metallic objects may also be covered carefully or, what is better, coated with vaseline. Sulphur, at the rate of four pounds to every 1000 cubic feet of space, is placed in a shallow iron pot or skillet which is placed on bricks or stones in a tub in which there is a little water in order to prevent spilling out and igniting the floor. The sulphur is easily ignited by pouring over it a few ounces of wood alcohol (or grain alcohol) and then lighting it with a match. Fumigation must continue for at least two hours, when the doors and windows should be opened to ventilate the room before occupancy.

While sulphur fumes (sulphur dioxid) are extremely useful against insects and other animal life, such as rats and mice, the liability to bleach fabrics and paper, and tarnish metals is against this method unless conditions are absolutely dry.

The natural enemies of the bedbug, such as red ants and cockroaches, do not enter in as practical factors, inasmuch as they are just as undesirable as the bedbug itself.

Repellents have had little or no consideration; however, old residents, who have had to live under conditions where bedbugs were plentiful, *e.g.* taverns and inns, state that they have found great relief in the use of leaves of the "bay tree" merely placed among the bedding.

B. The Cone-Noses

Order Hemiptera, Family Reduviidæ

The Reduviidæ. — Members of the family Reduviidæ as typical representatives of the order Hemiptera, suborder Heteroptera, have the basal half of the wing covers thick and leathery. The mouth parts, (Fig. 26), which are piercing structures *par excellence,* consist of a three-jointed proboscis extending from the extreme distal end of the head, and directed backward between the fore coxæ while at rest. The rather cone-shaped form of the head gives rise to the popular term "cone-noses" applied to certain of these insects. The long, slender, four-segmented, naked antennæ (basis for the term Gymnocerata) are located in front of the prominent eyes on the border of the head. The Reduviidæ are predaceous in their feeding habits to a marked degree, hence the term "*assassin bugs.*" Creeping slowly toward their victims, these assassins suddenly pounce upon the unsuspecting insect, into which are thrust the strong, sharp, needle-like stylets and the juices sucked out. The victim is ordinarily another insect; however, there are several species of cone-noses which evidently feed on mammalian blood if the opportunity is offered.

Many of the recorded cases of cone-nose bites indicate that the "bite" inflicted was not "premeditated," but quite accidental or rather an act of self-defense. The writer's first experience with a cone-nose was while incautiously plucking a leaf from a tree. The bite was instant and the pain most intense, and though the wound was on the finger the pain seemed to extend to the head and was followed by a feeling of faintness. The recovery, however, was but a matter of less than half an hour with no after effects except for a slight local cellulitis.

The *kissing bug* scare of 1899 was traced to the presence of what was perhaps an unusual abundance of Reduviidæ of a given species, and the fact that individuals were commonly bitten about the lips and face gave rise to the above popular cognomen. Many of these bites were pretty surely induced by grasping the insects with the fingers as they flew into the face at night. The common kissing bug (*Opsicoetes* (*Reduvius*) *personatus*) is strongly positively phototropic, hence dashes vigorously at a light and often into the face of any one near by.

Opsicoetes (*Reduvius*) *personatus* Linn. is one of the commoner species of Reduviids, having a wide distribution, ranging over the entire eastern part of the United States as far west as the Rocky Mountains. It is originally a European form and has now become well-nigh cosmopolitan. This insect is about two centimeters in length, and is coal black. The prothorax in dorsal aspect has two prominent tubercles or swellings, due to a median, dorsal, longitudinal groove and a transverse posterior groove. The young present a very curious masked appearance because of a covering of lint and dust, which adheres to the body by means of a sticky secretion.

This species is commonly known as the "kissing bug" which provided much "story" material for the newspapers of the Eastern states during the summer of 1899. It inflicts a very painful wound. Howard [1] quoting LeConte writes: "This species is remarkable for the intense pain caused by its bite. I do not know whether it ever willingly plunges its rostrum into any person, but when caught or unskillfully handled it always stings (pierces). In this case the pain is almost equal to that of the bite of a snake, and the swelling and irritation which result from it will sometimes last for a week. In very weak and irritable constitutions it may even prove fatal."

Conorhinus sanguisuga Lec. is known as the "blood-sucking cone-nose," also called the "big bedbug." Conorhinus is probably a typical South American and Mexican genus, but this species is commonly found in the Southern states of the U. S., occurring as far north as southern Illinois and Ohio. The "big bedbug" has secured this name for itself because of its frequent presence in bedrooms and beds. Since several species of the Reduviids are known to capture and feed on bedbugs it is quite likely that this species shares this habit, probably pre-

[1] Howard, L. O., 1899. The Insects to which the name "Kissing Bugs" became applied during the summer of 1899. U. S. Dept. of Agric., Div. Ento. Bull. No. 22.

ferring human blood second-hand, but will just as soon partake of this luxury at first hand if the opportunity offers itself.

This cone-nose is from 2 to 2½ cm. in length, and is dark brown in color with pinkish segmental markings on the dorsal borders of the abdomen and on the tips and bases of the hemi-elytra. In other respects it is a typical Reduviid of the fiercest appearance. The bite, if anything, is even more severe than that of the former species and results in more uniform symptoms. Because of the uniform character of the symptoms Marlatt suggests that a specific poison is injected into the wound. There is ordinarily " a burning pain, intense itching and much swelling " with the appearance of " red blotches and welts all over the body and limbs." The effects of the bite may last for months; however, they usually disappear within a few days.

Conorhinus protractus Uhler (Fig. 67), commonly known as the "China bedbug," is a widely distributed Pacific Coast species and is responsible for the large majority of cone-nose bites in California, where it has been reported from many localities. This species is frequently found indoors and averages 18 mm. in length, and is nearly dead black in color throughout. The abdomen is broad with a wide margin exposed around the narrow folded wings lying in the dorsal concavity. Van Duzee reports collecting this species commonly in the nests of wood rats.

FIG. 67. — A cone-nose, *Conorhinus protractus*, also known as the China bedbug. × 2.1.

The symptoms produced by *Conorhinus protractus* are ordinarily described by local physicians, viz.: "In a few minutes after a bite the patient develops nausea, flushed face, palpitation of the heart, rapid breathing, rapid pulse, followed by profuse *urticaria* all over the body. The symptoms vary with individuals in their intensity." Inquiries with regard to this species are most frequent during May and early June.

Melanolestes picipes H. S. resembles the above very closely, but is more slender and is a typical field species, as is *M. abdominalis* H. S. and *Apiomerus crassipes* Fabr., the latter a heavy-set, pilose, droll-looking creature, — all of these inflict painful bites.

Rasahas biguttatus Say, the "two-spotted corsair," is quite common in the Southern states, Cuba and South America, and, according to Van Duzee, giving way in the northwest and California to *R. thoracicus* Stal (Fig. 68), a very closely related form. The writer has taken this latter species in many parts of California from the Imperial Valley to the Sacramento, but has only a few records of its attacking human beings, though Howard[1] reports thus: "Dr. A. Davidson, formerly of Los Angeles, in an important paper entitled 'So-called Spider Bites and their Treatment' published in the *Therapeutic Gazette* of February 15, 1897, arrives at the conclusion that almost all of the so-called spider bites met with in southern California are produced by no spider at all but by *Rasahus biguttatus*. The symptoms which he describes are as follows: Next day the injured part shows a local cellulitis with a dark central spot; around this spot there frequently appears a bulbous vesicle about the size of a ten-cent piece and filled with a dark grumous fluid; a smaller ulcer forms underneath the vesicle, the necrotic area being generally limited to the central part, while the surrounding tissues are more or less swollen and somewhat painful. In a few days with rest and proper care the swelling subsides, and in a week all traces of the cellulitis are usually gone. On some of the cases no vesicle forms at the point of injury, the formation probably depending on the constitutional vitality of the individual or the amount of poison introduced."

FIG. 68. — The "two-spotted corsair," *Rasahus biguttatus* var. *thoracicus*. × 2.1.

This species has also the reputation of being a bedbug hunter.

Life History. — Though the life history (Fig. 69) of but a very few species of Reduviid has been worked out completely, it seems likely that all the species mentioned have but one generation a year. The eggs of *Conorhinus sanguisuga* are said to be white at first, then yellow, and finally become pinkish in color; they are barrel-shaped and are deposited on end, the compact mass of twenty-five to thirty forming a rather regular five or six sided figure. The young insects emerge in about twenty days. The metamorphosis is simple. *Conorhinus protractus* deposits its large white eggs (few in number)

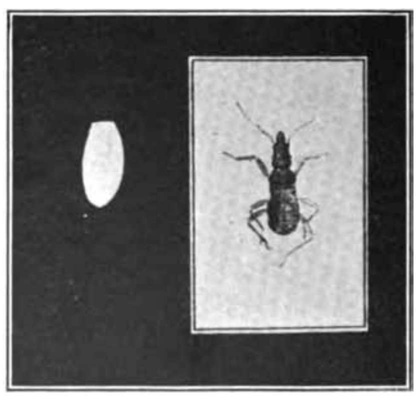


FIG. 69. — Egg (left) and larva (right) of a cone-nose, *Conorhinus protractus*. × 4.4.

[1] Howard, L. O., 1899 (*loc. cit.*).

during midsummer and these hatch ordinarily in about three weeks, the first molt taking place in seven or eight days after hatching.

Chagas Disease (Brazilian Trypanosomiasis). — In 1909 Chagas [1] reported from Brazil an endemic human trypanosomiasis. This disease occurs in its acute form in infants and in its chronic form in adults. It is characterized by an irregular fever, anæmia, enlargement of lymphatic glands, particularly an enlargement of the thyroid. The causative organism *Schizotrypanum cruzi* Chagas is said to be present in the peripheral blood of children during the fever, but in adults and children during later periods occurs in the cells of the thyroid, bone marrow and other tissues, resembling *Leishmania* during its segmentation stage. The flagellate form is said to enter the lungs of the host, where the flagellum is lost and an oval form is taken on.

Chagas found the protozoön in the intestine of a cone-nose, *Conorhinus megistus* Burm. (also referred to the genus Triatoma), and succeeded in transmitting it through the cone-nose to rodents. As reported, the incubation period (after the bite) varies from ten to fourteen days.

There is some difference of opinion as to mode of transmission; Chagas evidently believing that the parasites multiply in the intestine of the cone-nose, passing thence to the salivary glands, infection taking place directly with the bite. Brumpt,[2] on the other hand, says that infection results through the infective dejecta of the insect deposited upon the skin of the host when the insect bites, inoculation taking place through the mucous membrane of the mouth, inasmuch as the cone-nose usually bites the face and lips of sleeping persons.

Control. — The conspicuous size of these insects should make it an easy matter to find them in bedrooms, when it is known that they are common.

Since they are attracted by light at night, it is wise to screen windows and doors. Considerable precaution should be exercised when a specimen has alighted on the face or hands; do not grasp it between the fingers, this will pretty surely cause the insect to thrust its proboscis at once into the flesh. A quick snap of the finger will generally remove the intruder without any bad results, and the insect can then be crushed. They are, however, rapid in their movements.

Treatment for the Bite. — Treatment for the bite of cone-noses has usually a twofold object; first, to neutralize the specific poison of the cone-nose, and secondly, to prevent extra infection which is liable to occur because of the indiscriminate feeding habits of the insect. Bathing the wound with corrosive sublimate in proportions of 1 to 1000 is said to give good results, as will also ammonia.

[1] Chagas, C., 1909. Ueber eine neue Trypanosomiasis des Menschen. Memorias do Instituto Oswaldo Cruz, I, pp. 159–218.

[2] Brumpt, E., 1913. Immunite partielle dans les infections a *Trypanosoma cruzi* transmission de ce trypanosome par *Cimex rotundatus*. Rôle regulateur des hotes intermediaires. Passage a travers la peau. Bull. Soc. Path. Exot., Vol. VI, No. 3, pp. 172–176. (Abstract in the Review of Applied Ento., Ser. D., Vol. I, No. 7.)

CHAPTER IX

MOSQUITOES

Order Diptera, Family Culicidæ

General Characteristics. — As members of the Order Diptera, mosquitoes partake of the general characters of the order; namely, reduction of the metathoracic (posterior) pair of wings, in place of which

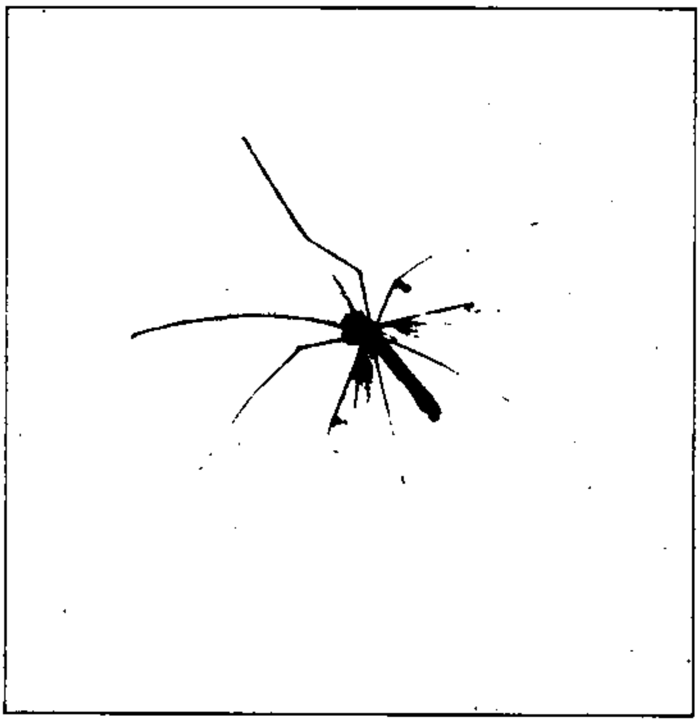


FIG. 70. — Crane fly (Tipula), often mistaken for a mosquito. Halteres visible immediately behind the wings. × 1.

there occurs a pair of tiny knobbed organs known as the halteres or balancers, most distinctly visible in the crane flies (Tipulidæ) (Fig. 70). The Diptera are commonly divided into two suborders, — first, Nematocera, in which the antennæ are many-jointed and filamentous, as in the mosquitoes (Culicidæ), crane flies (Tipulidæ), midges (Chironomidæ) and buffalo gnats (Simuliidæ); secondly, the Brachycera, in which the antennæ are short and not thread-like, as in the horseflies (Tabanidæ), house flies (Muscidæ) and botflies (Œstridæ).

The Culicidæ (mosquitoes) are distinguished from all other Nematoceran Diptera by (1) the character of the wing venation (Fig. 71), which varies also specifically within the family; (2) by the presence of characteristic scales fringing the wings and more or less abundant on the body and head (Fig. 78). The family may be divided into two

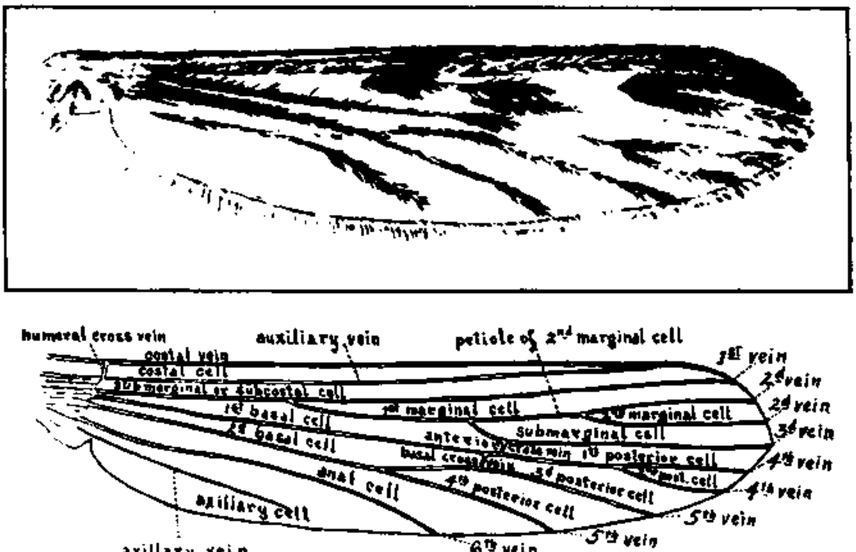


FIG. 71.—Showing (upper figure) scaly wing of a mosquito with spots of Anopheles; (lower figure) wing venation of a mosquito with veins and cells named and numbered for systematic purposes. × 23.

divisions: the Corethrinæ or short-beaked, non-blood-sucking mosquitoes, represented by the genus Corethra (Fig. 72), and the Culicinæ or long-beaked, blood-sucking true mosquitoes. The males of all mosquitoes are non-blood-sucking.

Nearest Allies. — There are many Dipterous insects which may be easily mistaken for mosquitoes unless a careful microscopical examination is made. For all practical purposes the characteristics referred to above should serve to determine whether the insect in hand is a mosquito or not. It is true that other families of Diptera are in some cases provided with scales, but other simple characters to be pointed out here should serve to eliminate these. The most commonly mistaken insects are members of the family Chironomidæ, the midges (Fig. 73). According to Williston these may be distinguished from mosquitoes in that the costal vein is not continuous on the posterior side of the wing.

The wings are usually bare or in some may be hairy. The proboscis is short, and in all except the "punkies" or "no-see-ums" are non-blood-sucking. These latter are tiny gnats, but vicious biters. The most common Chironomids which often occur in enormous swarms over or near swamps have bare wings, plumose antennæ and do not bite. In size and general form they resemble mosquitoes very closely, particularly male mosquitoes.

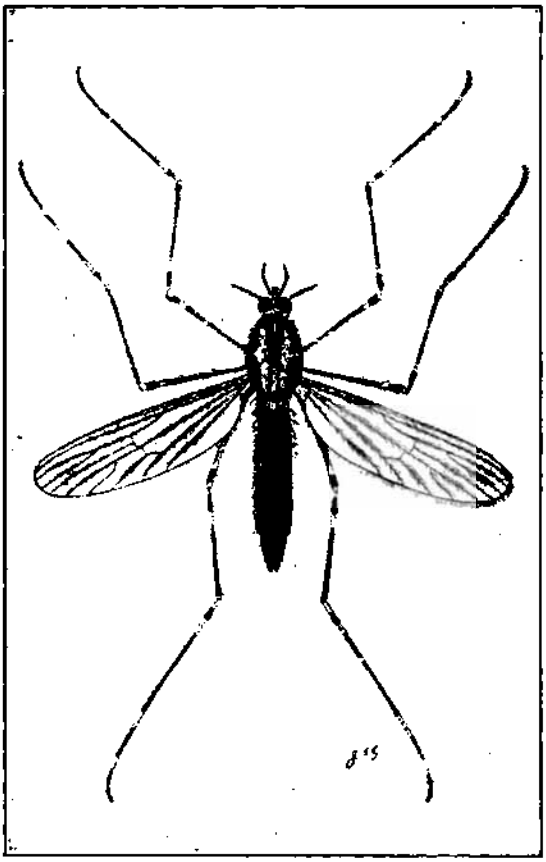


Fig. 72. — Corethra, easily mistaken for a mosquito, is an insect belonging to the family Culicidæ (note scaly wings) but is non-blood-sucking. (After Smith.) × 12.

Members of the family Tipulidæ, crane flies or "daddy long-legs" are commonly mistaken for mosquitoes. The commoner species are usually distinguished by the presence of a V-shaped suture situated dorsally on the thorax (mesonotum) (Fig. 74) and by the blunt, non-piercing mouth parts. The wings are usually devoid of scales or hairs (some exceptions). Other mosquito-like Diptera are the Dixa midges (Fam. Dixidæ), in which the mouth parts are blunt and the wing veins are devoid of scales; the family Psychodidæ includes the moth-like flies which are densely covered with hairs and are not easily mistaken for mosquitoes. The "papatici flies," members of this family and of the genus Phelebotomus, are blood-sucking and occur in the Philippine Islands, parts of Asia, Africa and South America.

Life History. — A general statement of life history as applied to mosquitoes is not possible if the time required for complete transformation is desired, inasmuch as this varies considerably for the genera and even for species. However, it may be said with certainty that all mosquitoes pass through a complex metamorphosis represented by the usual stages, *egg, larva, pupa* and *imago* (Fig. 75). The larvæ are commonly called "wrigglers" and the pupæ "tumblers." Water in which to pass the larval and pupal stages is absolutely essential. The eggs may be deposited on wet mud and the larvæ may exist for some hours in similar situations. With reference to this Howard states that "In no case, however, were we able to revive larvæ in mud from which the water had been drawn off for more than forty-eight hours, and after twenty-four hours only a small proportion of the larvæ revived."

The eggs of mosquitoes are deposited from early spring to early autumn, and in warmer parts active "wrigglers" may be found throughout the year. The writer has found nearly full-grown larvæ in parts of California in January and pupæ from which occasional imagines emerged during the month of February. These over-wintering larvæ are quite certainly from eggs deposited late in the autumn and in which growth is very slow. Mosquitoes which make their appearance early in the spring are, as a rule, individuals which have been in hibernation during the winter.

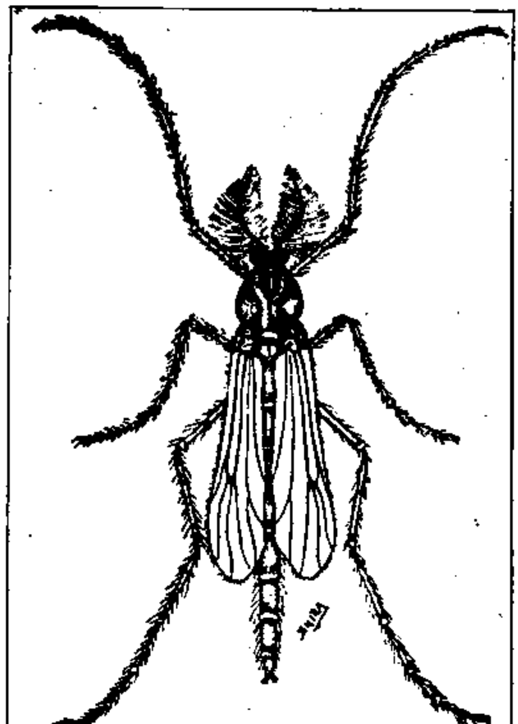


Fig. 73. — A midge (Chironomidæ), often mistaken for a mosquito. (After Osborn.) × 12.

Probably about ten days is the shortest time for any of the commoner species of mosquitoes to pass through the various developmental stages; Howard gives the time for *Culex pungens* as "sixteen to twenty-four hours for the egg, seven days for the larvæ, and two days for the pupa." From this rather short life-history period the time required to pass through the same transformation may be two or three weeks, and under lower temperature conditions, several months. At a maintained temperature of 24° ± 1° C. *Culiseta incidens* required about twenty-four hours for the eggs to hatch, the larvæ molted on the fourth day after hatching and again on the eighth day, pupating on the eleventh day, thus giving about ten days for the larval period; mosquitoes emerged on the second day after pupation, requiring about thirty-six hours for this stage. The mosquitoes were given a suck of blood within twenty-four hours and in four days thereafter deposited eggs. This gives a period of about eighteen days from egg to egg under favorable conditions.

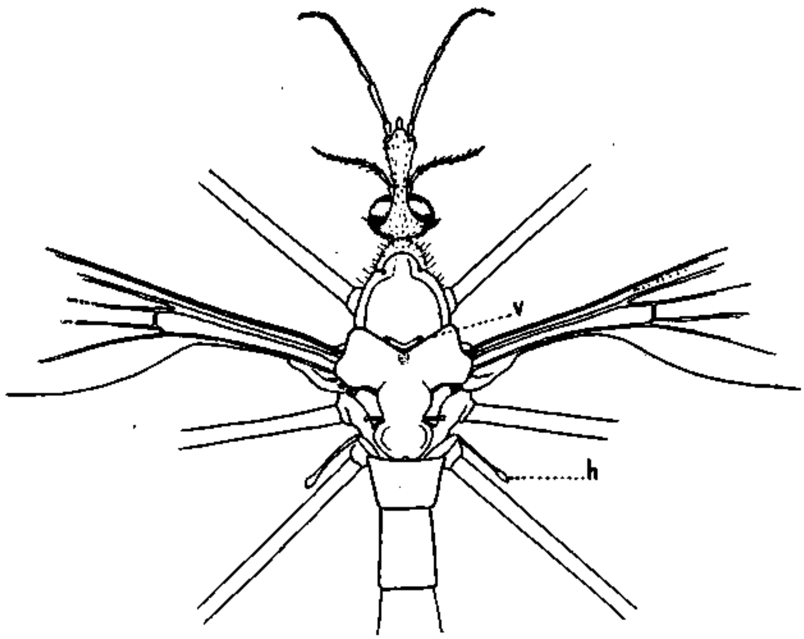


FIG. 74. — Head and thorax of a crane fly (Tipulidæ), showing appendages, halteres (*h*) and characteristic v-shaped suture on thorax (*v*).

The longevity of the female mosquito is a matter not so easily determined because of the conditions needed in ascertaining this; outdoor observations naturally offer a great handicap to the observer. By feeding mosquitoes on ripe banana and blood, it has been possible to keep them in captivity as long as two months, but this is probably longer than the average, because by far the greater number of females die in captivity within two or three weeks, while the males only live three or four days. It should be remembered, of course, that mosquitoes in *hibernation* may live as long as six or seven months. It is quite probable that the average active lifetime of the female mosquito under natural conditions will be found to be pretty close to thirty days, as the writer has observed for several species of Sarcophagid and Muscid flies.

Internal Anatomy. — To be prepared to study the relation of mosquitoes to such diseases as malaria and filariasis the student must be familiar with their internal anatomy, which offers specializations of importance.

The alimentary canal is separable into three regions, the *fore-*, *mid-* and *hind-gut*, each of which is again subdivided into more or less distinct divisions (Fig. 76). Thus the fore-gut consists of the sucking

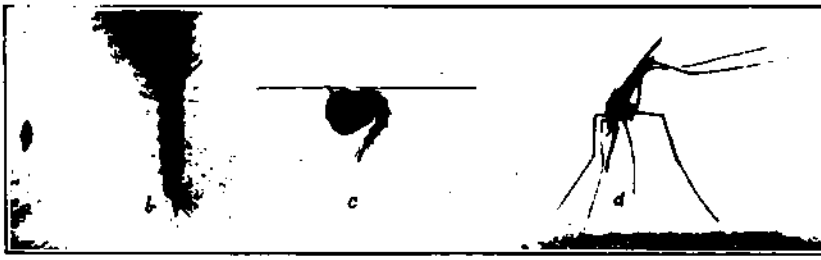


FIG. 75. — Illustrating the life history of a mosquito (*Anopheles quadrimaculatus*). *a.* egg; *b.* larva or wriggler (viewed from above); *c.* pupa or tumbler; *d.* adult. × 5.

tube of the *proboscis*, the *pharynx*, including pumping organ and the *esophagus* with its diverticulæ (two or three in number and known as food reservoirs); the mid-gut consists of a narrower anterior portion

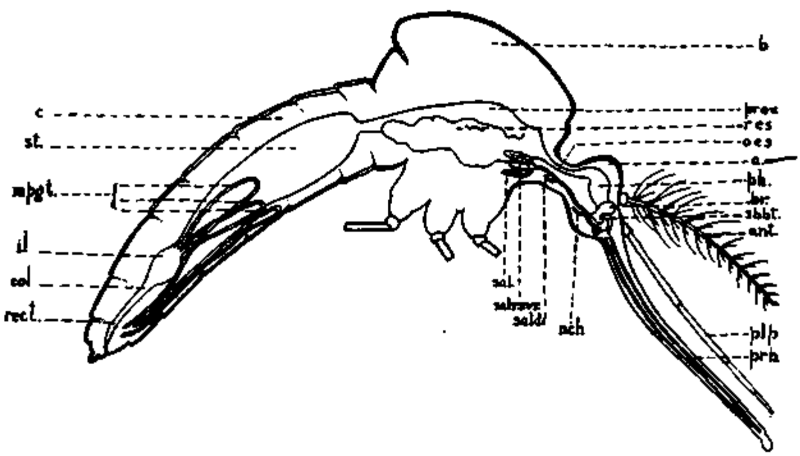


FIG. 76. — Internal anatomy (in part) of a mosquito. *a.* head; *b.* thorax; *c.* abdomen; *ant.*, antenna; *plp.*, palpus; *prb.*, proboscis; *br.*, brain; *sbbt.*, subesophageal ganglion; *nch.*, ventral nerve chord; *ph.*, pharynx; *oes.*, esophagus; *res.*, food reservoir, of which there are three (esophageal diverticula); *prov.*, proventriculus (false); *st.*, stomach or mid-gut; *il.*, ileum; *col.*, colon; *rect.*, rectum; *mpgt.*, Malpighian tubules; *sal.*, salivary gland; *salvsr.*, salivary reservoir; *sald.*, salivary duct. (Adapted after various authors and based on dissections.)

(false proventriculus) and a wider posterior portion (*stomach*) occupying the thorax and much of the abdomen, and limited posteriorly by the origin of the five *Malpighian tubules* which indicate the beginning of the viscera or hind-gut; the hind-gut is bent on itself several times and consists of the narrow, longer *ileum*, the colon and what is arbitrarily termed *rectum* marked anteriorly by a slight constriction.

The *salivary system* consists of two sets of salivary glands (right and left), three glands to each set (Fig. 76). These organs are situated ventrally in the thorax near the neck. Each set of glands empties into a duct which combines with the opposite one to form the common salivary duct. This common duct empties its contents into the esophagus through the salivary receptacle close to the base of the proboscis.

The *reproductive system* of the female mosquito occupies the posterior portion of the abdomen and comprises a pair of ovaries joined by a pair of oviducts terminating in the *vagina* and *ovipositors*, one to three (depending on the species); *spermathecæ* are present. The spermathecæ of an impregnated female contain myriads of spermatozoa, and the ovaries when mature occupy the larger part of the abdomen.

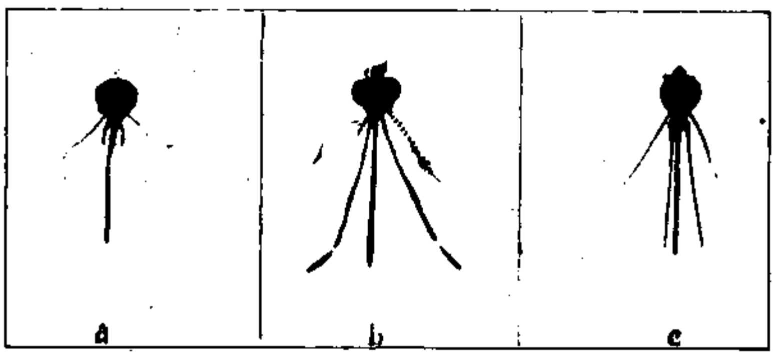


Fig. 77. — Heads of mosquitoes, showing relative length of palpi. Useful in distinguishing the two main subdivisions of mosquitoes. *a.* Culicine; *b.* male of either group; *c.* Anopheline.

Sexual Differences. — The males of many species of mosquitoes are provided with plumose antennæ (Fig. 77); in the female, as a rule, these organs are slender, thread-like and covered with short lateral hairs. In the males the palpi are with few exceptions long (as long or longer than the beak), conspicuous, jointed organs and quite hairy (Fig. 77*b*). In the Ædinæ the palpi are short in both sexes. Inasmuch as males do not feed on blood they are less frequently found about human habitations. Sweeping with the insect net in grass or other low vegetation will usually result in the capture of males if there is a breeding place near and it is the proper season.

Characters of Systematic Value. — Although most authors have discarded the relative length of palpi as a useful character in separating the Culicinæ into three divisions or tribes, we still find this very useful, particularly in localities where malaria control work is in progress. On this basis the tribe **Culicini** includes mosquitoes in which the palpi of the females are less than half as long as the proboscis (Fig. 77*a*); the tribe **Anophelini** includes mosquitoes in which the palpi of the females are nearly or quite as long as the proboscis (Fig. 77*c*). The males of both tribes are provided with palpi as long as or longer than the proboscis, except in what were formerly designated the Ædini, in which the palpi of both males and females are short; the palpi are commonly quite hairy, as are the antennæ (Fig. 77*b*).

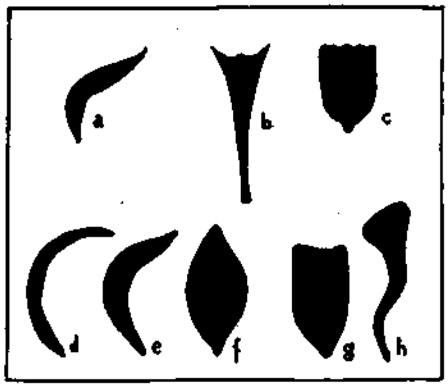


FIG. 78. — Varieties of Culicid scales. *a*, *b*, *c*, head scales, (*a*) narrow curved, (*b*) upright forked, (*c*) flat; *d–h*, thoracic scales. (Redrawn after Stephens and Christophers.)

The determination of the genera and species by some authors is based quite largely on the character of the scales. The scales on the head and body are of several varieties, as shown in Fig. 78. The occurrence and arrangement of these scales on the head, thorax, abdomen and wings provides a basis for distinguishing the genera, as illustrated by Fig. 79. Stephens and Christophers state, "All mosquitoes belonging to the genus Culex have on the head (1) narrow curved and (2) upright forked, but only (3) a few flat scales laterally; whereas all

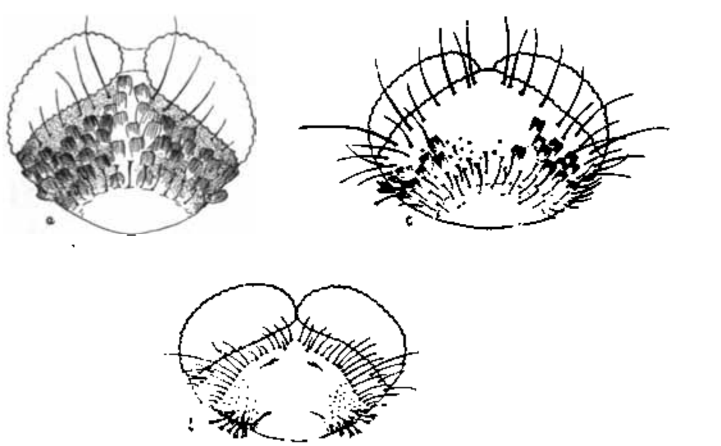


FIG. 79. — Occurrence and arrangement of scales on the heads of mosquitoes. (*a*) Stegomyia; (*b*) Anopheles; (*c*) Culex. (Redrawn in part after Stephens and Christophers.)

mosquitoes belonging to the genus Stegomyia have on the head (1) no narrow curved scales, (2) a few upright forked and (3) flat scales, covering the whole of the head." In Anopheles there are "upright forked scales only on the head."

The *unques* or tarsal claws are also useful characters in local classification. In some species the claws are not toothed and in others the claws are toothed.

The spotting of the wings is not a safe character to separate the Culicini from the Anophelini, although all except two or three species of Culicines have unspotted wings, and all but one or two Anopheline species have spotted wings. *Culiseta* (*Theobaldia*) *incidens*, a very common Culicine mosquito of California and elsewhere, has conspicuously spotted wings.

Anopheline Mosquitoes

Adults. — As already stated, the Anophelini are roughly distinguished from the Culicini by the presence of long palpi in both males and females (Fig. 77). The proboscis is always straight and the scutellum is simple, never trilobed (Stephens and Christophers). The commoner Anopheline species of North America have also a characteristic resting attitude (Fig. 80), *i.e.* the body is usually thrown up at an angle with the surface upon which the insect is resting; this angle is the greatest when the individual is resting on the ceiling, for the reason that gravity acts then more strongly on the heavy abdomen. When resting on a table or other horizontal surface, this angle is not so noticeable, but in all cases the proboscis is nearly or quite on a line with the body, whereas in the Culicini the beak and body form a distinct angle.

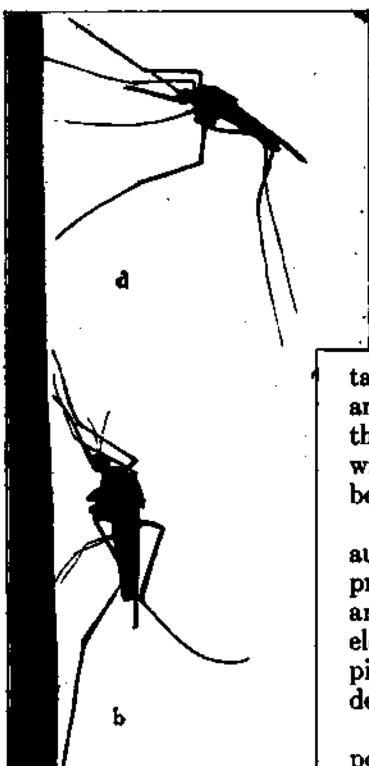


Fig. 80. — Characteristic attitude of adult mosquitoes at rest. *a*. Anopheles with body normally at an angle of from 25° to 55° with the surface; *b*. Culex, with body parallel. × 8.

The hum of Anopheles is all but inaudible; where the Culicine mosquito produces a high-pitched, tantalizing tone and is quickly brushed away, the Anopheles may alight and actually proceed to pierce the skin of the victim before it is detected.

Eggs. — The Anopheline female deposits from 75 to 150 ova, while the Culicini deposit a larger number, often from 250 to 450. In the former case (including *Ædes* (*Stegomyia*) *calopus* and other Ædini) the individual eggs lie flat on the surface of the water and often form geometrical figures with each other, owing to their peculiar form; in the latter (Culicini) (excepting *Ædes* (*Stegomyia*) *calopus* and other Ædini) the eggs are placed on end, forming a boat-shaped pack or raft (Fig. 81).

On examination it will be seen that the individual canoe-shaped Anopheline egg is provided on the upper surface with a pair of floats

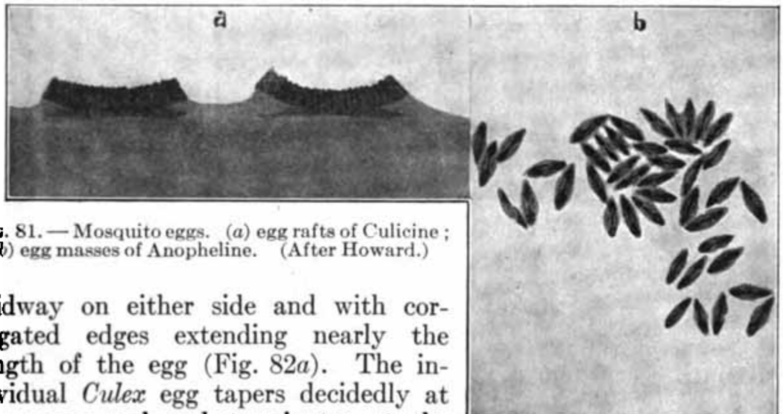


Fig. 81. — Mosquito eggs. (*a*) egg rafts of Culicine; (*b*) egg masses of Anopheline. (After Howard.)

midway on either side and with corrugated edges extending nearly the length of the egg (Fig. 82*a*). The individual *Culex* egg tapers decidedly at the upper end and terminates at the base in a globular organ called the "micropilar apparatus" (Fig. 82*b*).

Larvæ. — The larvæ of Culicine mosquitoes (Fig. 83*a*) are always suspended from the surface of the water at a decided angle with only one portion, the anal siphon, touching and penetrating the film, while in Anophelinæ (Fig. 83*b*) the larvæ lie horizontal with at least several body segments coming dorsally in contact with the film. At the point of contact each segment is provided with a group of hairs arranged fanlike. The eighth abdominal segment in both groups is provided with a specialized organ through which the tracheæ (breathing organs) come in contact with the outer air. In the Culicini this apparatus is prolonged into a definite breathing tube (siphon), while in the Anophelini this tube is absent, or only slightly protuberant and not chitinous as in the former (Fig. 83). So abundant are the wrigglers at times that a small pool may be literally black with them. Dr. J. B. Smith made some observations with reference to numbers in *Anopheles crucians* and found that a

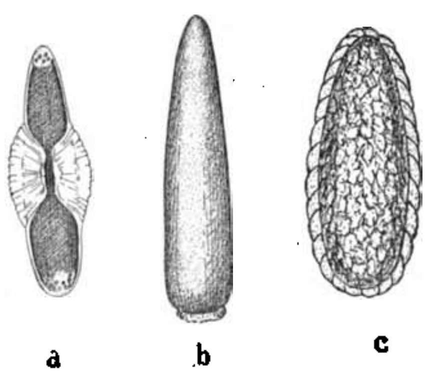


Fig. 82. — Individual mosquito eggs. (*a*) Anopheles; (*b*) Culex; (*c*) Stegomyia. (Adapted after Mitchell.)

pond with an area of 1894 square feet contained 10,636,700 wrigglers, roughly ten and one half millions, or 5616 to every foot of area.

The movements of Anopheline larvæ are very much more jerky than those of the Culicine, in which the wriggling motion is worm-like. The former are also not so easily seen as are the latter, probably owing to their horizontal position at the surface of the water. On wading into a swamp no larvæ may be visible, but on looking backward into the now muddy water, the larvæ may be plainly seen, distinctly outlined against the murky background.

A close examination of the feeding Anopheline larvæ will show that the head is turned dorsally and that the smaller organisms (animal and

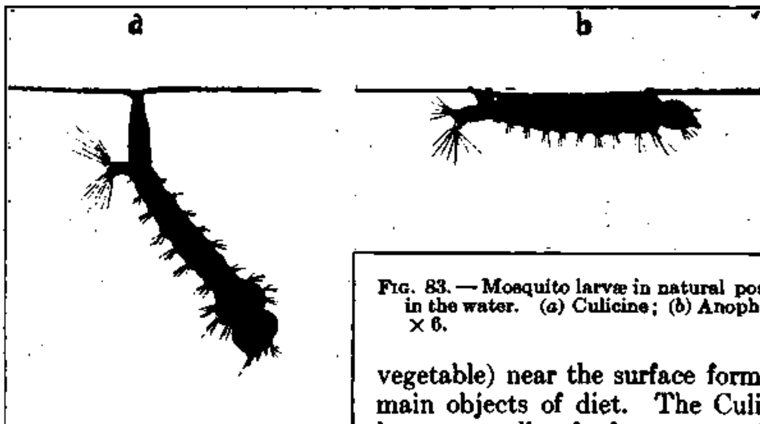


Fig. 83. — Mosquito larvæ in natural position in the water. (*a*) Culicine; (*b*) Anopheline. × 6.

vegetable) near the surface form the main objects of diet. The Culicine larvæ usually feed on organisms located at the bottom of shallow pools and at the sides of vessels, etc.

Pupæ. — The pupæ or nymphs of all mosquitoes are very similar. In all cases, instead of the single posterior breathing apparatus of the larva, there are present a pair of breathing trumpets (right and left) located on the thorax, *i.e.* anteriorly. The position of these trumpets in the two general groups of mosquitoes is different and fairly distinctive, *i.e.* they are located farther forward on the thorax in Anophelini, near the middle, and open broadly in this group, being more slender and relatively longer in the Culicini.

In position the two groups also differ somewhat, *i.e.* the Anopheline pupæ hang more horizontally, and the heavier "head-end" is relatively longer.

Life History. — As in all other mosquitoes and insects in general the life history depends greatly on temperature. In early spring and late autumn the development is retarded, owing to the lower average temperature.

In midsummer the egg stage is rarely longer than twenty-four hours and often nearer twelve hours duration. The larva emerges by splitting the egg (Fig. 84) (or in the Culicini by pushing the bottom from the egg) and begins its existence in the water, usually clinging close to débris or scum. The larval stage is most easily affected by temperature, but lasts usually from twelve to fifteen days, during which time the skin is shed several times. The change into the nymphal or pupal stage is undergone very rapidly and usually occurs overnight;

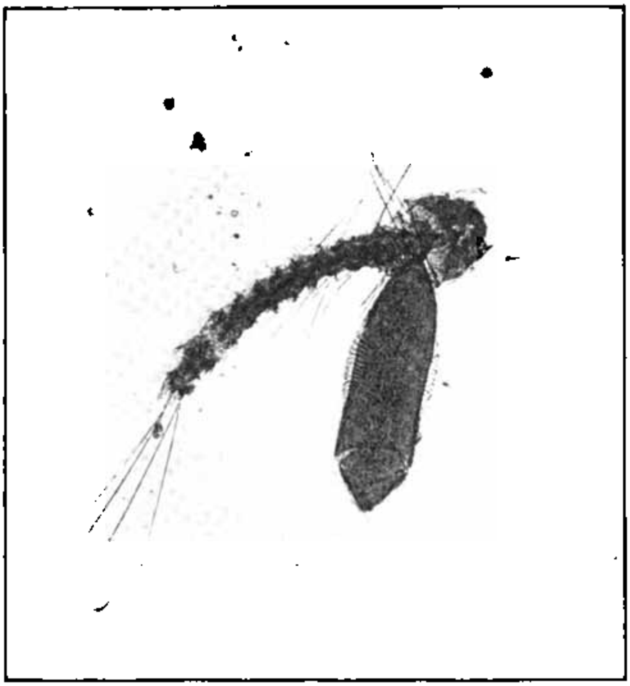


FIG. 84.—Anopheles mosquito larva just emerged from the egg. × 50.

great numbers may undergo this change in the early part of the night between nine o'clock and midnight. This stage is comparatively short, requiring seldom over thirty-six hours. At the end of this time the pupal skin bursts along the mid-dorsal side, the pupa in the meantime having straightened out. In a few minutes the adult has pulled itself out of the pupal skin, and quietly balancing itself, remains on top of its cast skin until its wings are sufficiently dry to permit it to fly away. Thus it must be inferred that the process of emerging requires a very quiet body of water, otherwise the mosquito would be submerged and perish.

Duration of Adult Life.—As a rule the newly emerged females will suck blood after a period of about twenty-four hours. Numerous experiments tried on the male mosquito as well as extensive field observations seem to give conclusive evidence that this sex does not possess the blood-sucking habit, living exclusively on the juices of plants and "plain" water. However well one may care for the males they invariably die within a week, usually in about three days, and it is quite probable that very little nourishment is taken during this time.

In captivity the mosquito mortality is very high, and it is therefore not a satisfactory plan to estimate the average length of life on the basis of laboratory observations. Basing an estimate on the relative abundance of Anopheline mosquitoes in a given district during several weeks after careful control measures are inaugurated, it seems safe to say that the average life of the adult female mosquito is between thirty and forty days, perhaps nearer thirty. This does not, of course, refer to hibernation. Ordinarily the female mosquito dies shortly after she has deposited her eggs.

Flight. — It is a matter of common observation that Anopheline mosquitoes are not strong fliers. If Anopheles are found, one can rest assured that their breeding place is somewhere very near, usually within two hundred yards. They are seldom found over a mile away. However, if the breeding place of these insects is connected with human habitations by means of low herbage at close intervals, this will afford a ready means of advance. On the other hand, it seems that a belt of trees tends to act as a barrier.

Unlike certain other species of mosquitoes, notably salt-marsh mosquitoes, the Anopheles are not readily carried by the wind, inasmuch as they take to cover even in a moderate breeze and cling to vegetation.

Hibernation. — The writer has been bitten by Anopheles mosquitoes in California as early as February 12, and at noonday at that, and a specimen was captured in the act of flying about in a church on the first of January. Since all breeding had ceased in late October, it must be assumed that these were hibernated individuals which had been induced to leave their shelters by the appearance of balmy days. In the colder Eastern states there are no winter days when it is balmy enough to induce mosquitoes to come forth from their places of hibernation.

The first case mentioned was a normal response to the usual early spring days in California, where breeding begins correspondingly early. The day before, *i.e.* February 11, mosquitoes were seen emerging from beneath a schoolhouse which had afforded a place of hibernation during the heavy rains. This place had probably been sought early in November.

The above and other similar experiences afford ample evidence that Anopheles mosquitoes which have been in hibernation are active on emerging even by daylight (noonday) and bite fiercely during that time.

Yellow Fever Mosquitoes

Adults. — Mosquitoes belonging to what was formerly known as the genus Stegomyia (now Ædes), of which there were twenty or more species, are all beautifully marked with silvery white or yellowish white bands and stripes on a nearly black background, whence the name " tiger mosquitoes " applied to the members of this group.

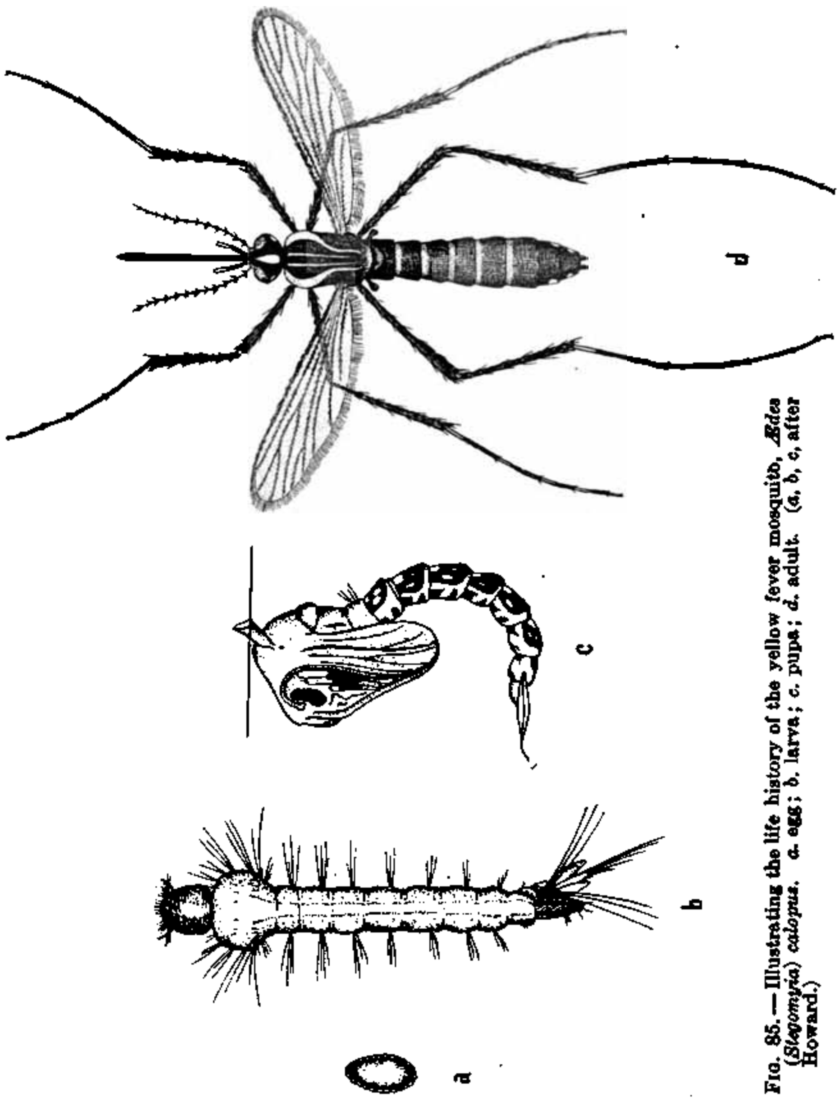


FIG. 85. — Illustrating the life history of the yellow fever mosquito, *Ædes (Stegomyia) calopus*. *a.* egg; *b.* larva; *c.* pupa; *d.* adult. (*a, b, c,* after Howard.)

Ædes calopus Meig. (*Stegomyia fasciata* Fabr.), with which we are principally concerned, has a "lyre-like" pattern (Fig. 85*d*) on its back (thorax), *i.e.* two outer curved yellowish white lines and two median parallel lines. The legs are also conspicuously banded, the distal portion of each segment being whitish and the terminal tarsal joint entirely white. An examination of the head in this genus shows it to be covered with broad flat scales (Fig. 79) with only a single row of upright forked scales.

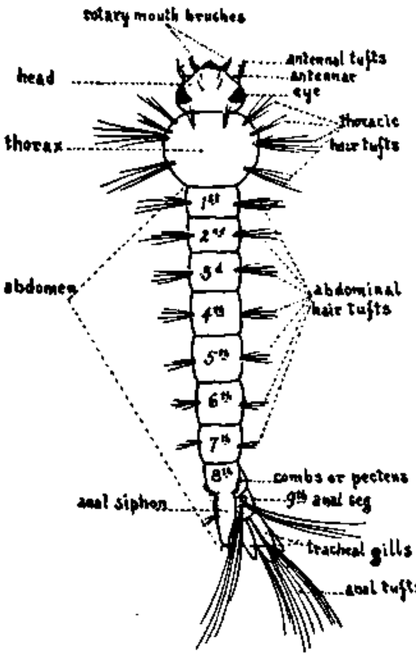


Fig. 86. — A mosquito larva with parts used in classification named. (Adapted after J. B. Smith.)

The yellow fever mosquito is commonly known as the "day-flying mosquito." This, however, only applies to the younger individuals up to six or seven days, after which they become nocturnal like other mosquitoes.

The distribution of the yellow fever mosquito marks it as a tropical and subtropical species. Theobald refers it to 38 degrees north and south latitude. Howard[1] points out that this mosquito "does not thrive below a temperature of 80° F., so that in a uniform climate with a temperature much below 80° the species will not continue to exist." The same author also states that it is probable that it has a wide range south of the Mason and Dixon line in the United States. Yet California, owing probably to its cold nights, is free from this species, at least north of San Diego.

The yellow fever mosquito is typically a domestic species, found abundantly in towns. Like the Anopheles this mosquito is silent in its flight. It is said to be extremely wary. Howard observes that "it prefers the blood of white races to that of dark races, and attacks young, vigorous persons of fine skin and good color in preference to anæmic or aged people."

Eggs. — The eggs of the yellow fever mosquito are deposited singly, are dark in color and each egg is surrounded by air cells (Fig. 82*c*). As in the Anopheles comparatively few eggs are deposited at one laying, *i.e.* from perhaps less than fifty to a hundred, and there may be several layings.

[1] Howard, L. O., 1913. The Yellow Fever Mosquito, U. S. Dept. of Agric., Farmers' Bull. 547.

Unlike the eggs of most species these can withstand desiccation to a very marked degree, some authors declaring that this is possible for several months. Ordinarily the eggs hatch in about forty-eight hours.

Larvæ. — The larvæ are quite stalky, the breathing siphon is comparatively short and heavy (Fig. 85*b*), and their position in the water is almost vertical, considerably more so than other Culicine species. The larval stage is ordinarily passed in about nine or ten days under average conditions.

Pupæ. — The pupæ are characteristically Culicine; the breathing trumpets are, however, broadly triangular. Only about thirty-six hours is spent in this stage.

Life History. — The yellow fever mosquito breeds by preference in artificial pools of rain water. (They are known, however, at times to breed naturally in brackish water.) Rain-water barrels, tanks, cisterns, tin cans, urns, etc. provide suitable places, also water collected between the leaves of certain members of the Agave family; ornamental banana palms are often a great menace in this respect.

According to Howard the shortest period of development from egg to imago observed by Reed and Carroll in Cuba was nine and a half days, viz.: egg stage, two days; larval stage, six days; pupal stage, thirty-six hours. From this very short period the time ranges from eleven to eighteen days according to the same author.

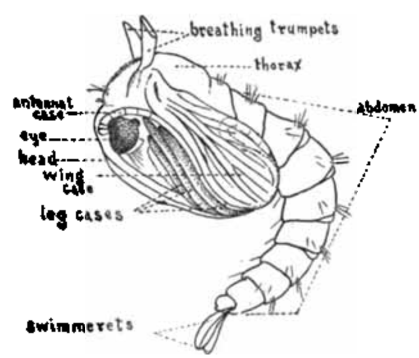


Fig. 87. — A mosquito pupa with parts used in classification named. (Adapted after J. B. Smith.)

Classification of Mosquitoes. — The principal characteristics on which the classification of mosquitoes is based are indicated in Figs. 86, 87 and 88, together with the scale characteristics shown in Fig. 78 and wing venation shown in Fig. 71.

The following key, adapted after Stephens and Christophers and Giles, according to Theobald, is not intended to be comprehensive and is only adapted for the purpose of this work. For a complete key including all known mosquitoes, the reader is referred to Theobald's *Monograph of the Culicidæ of the World*.

Key for Classification of Mosquitoes

A. Scutellum simple, never trilobed. Proboscis straight; palpi long in male and female . . . . *Anophelinæ*

AA. Scutellum trilobed

a. Proboscis strongly recurved; first submarginal cell very small *Megarhininæ*

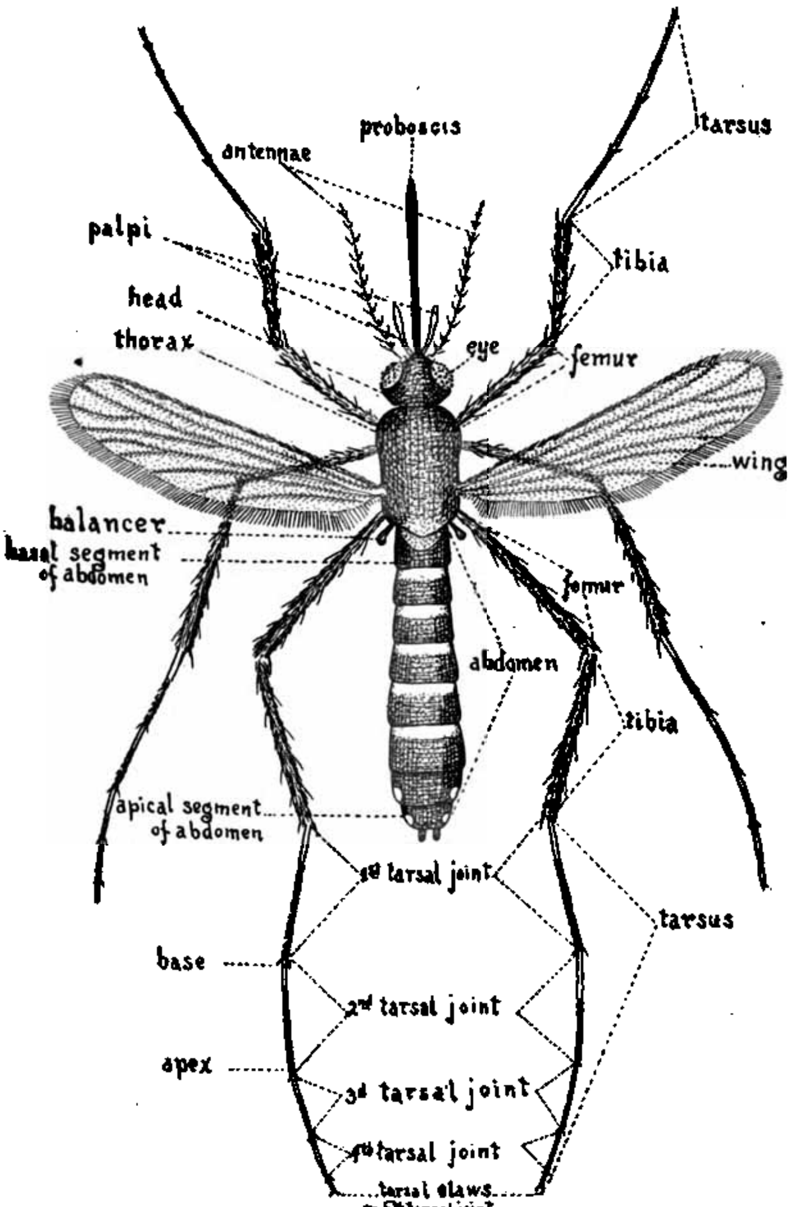


FIG. 88.—An adult mosquito with certain parts used in classification named. (Adapted after J. B. Smith.)

aa. Proboscis straight; metanotum nude.
1. Wings with six long scaled veins.
2. Antennæ with second joint normal in length.
3. First submarginal cell as long or longer than posterior cell.
4. Palpi of female shorter than proboscis, of the male long *Culicinæ*
4′. Palpi short in male and female . . . . *Ædinæ*

Subfamily Anophelinæ

Table of Genera

A. First submarginal cell large
I. Antennal segments without dense lateral scale tufts
a. Thorax and abdomen with hair-like curved scales. No flat scales on head, but upright forked ones.
Basal lobe of male genitalia of one segment
1. Wing scales large, lanceolate . . . Genus *Anopheles* Meigen
2. Wing scales mostly small, long and narrow or slightly lanceolate Genus *Myzomyia* Blanchard
3. Wings with patches of large inflated scales Genus *Cycloleppteron* Theobald

Basal lobe of two segments
4. Prothoracic lobes with dense outstanding scales Genus *Feltinella* n. g.

Median area of head with some flat scales; prothoracic lobes mammillated
5. Wing scales lanceolate . . . Genus *Stethomyia* Theobald

b. Thorax with narrow curved scales; abdomen hairy
6. Wing scales small and lanceolate; head with normal forked scales . . . . Genus *Pyretophorus* Blanchard
7. Wing scales broad and lanceolate; head with broad scales, not closely appressed but not forked or fimbriated Genus *Myzorhynchella* n. g.

c. Thorax with hair-like curved scales and some narrow-curved ones in front; abdomen with apical lateral scale tufts and scaly venter; no ventral tuft.
8. Wing scales lanceolate . . . Genus *Arribalzagia* Theobald

d. Thorax with hair-like curved scales; no lateral abdominal tufts; distinct apical ventral tuft. Palpi densely scaly.
9. Wing with dense large lanceolate scales Genus *Myzorhynchus* Blanchard

e. Thorax with hair-like curved scales and some narrow curved lateral ones; abdomen hairy with dense long hair-like lateral apical scaly tufts.
10. Wing scales short, dense, lanceolate; fork cells short. Genus *Christya* Theobald

f. Thorax with very long hair-like curved scales; abdomen with hairs except last two segments which are scaly. Dense scale tufts to hind femora.
11. Wings with broadish, blunt lanceolate scales Genus *Lophoscelomyia* Theobald

g. Thorax and abdomen with scales
12. Thoracic scales, narrow-curved or spindle-shaped; abdominal scales as lateral tufts and small dorsal patches of flat scales Genus *Nyssorhynchus* Blanchard
13. Abdomen nearly completely scaled with long irregular scales and with lateral tufts . . . . Genus *Cellia* Theobald

14. Similar to above, but no lateral scale tufts Genus *Neocellia*, n. g.
15. Abdomen completely scaled with large flat scales as in *Culex* Genus *Aldrichia* Theobald
16. Thoracic scales hair-like, except a few narrow-curved ones in front; abdominal scales long, broad and irregular Genus *Kerteszia* Theobald

II. 17. Antennal segments with many dense scale tufts Genus *Chagasia* Cruz

AA. 18. First submarginal cell, very small Genus *Bironella* Theobald

Genus Anopheles

Table of Species

a. Wings spotted, legs unbanded, costa unspotted.

1. *A. maculipennis* — Wing field four spots. Palpi unbanded. Europe, giving way to *A. quadrimaculatus* in North America.

2. *A. crucians* — White spots on dark veins. Three dark spots on sixth vein. Tarsi unbanded; palpi three white bands. North America.

3. *A. eiseni* — Apical fourth of hind tibiæ yellowish. Sixth vein wholly black. Guatemala.

aa. Wings spotted, legs unbanded, costa spotted.

4. *A. punctipennis* — Costa, characteristic yellow spot near apical fourth of wing fringe; no spots. North America.

5. *A. pseudopunctipennis* — Wings as in previous species but wing fringe with several yellow spots; (?) a distinct species. North America.

6. *A. franciscanus* — Small species; costa, a spot about middle, and a pure yellow apical spot; third vein white with two black spots. Fringe spotted. North America.

aaa. Wings spotted, legs banded.

7. *A. gigas* — Costa, two large costal spots. Legs with pale basal bands. A hill species. India.

8. *A. wellcomei* — Costa, two small yellowish spots. Legs with narrow apical bands. Sudan.

9. *A. arabiensis* — Costa, seven dark spots, four long and three short. Other veins much spotted. Fringe spots at all the vein junctions. Hind femur and tibia speckled — latter often has apical band. Palpi three white bands. Markings vary according to season. Arabia.

10. *A. dthali* — Costa, four black spots, the basal the longest. First long vein four black spots, other veins pale. Wing fringe, no spots. Palpi, pale with two white bands. Arabia.

aaaa. Wings unspotted, legs unbanded, thorax with abnormal pattern.

11. *A. corethroides* — resembles *A. bifurcatus*, but differs in (*a*) thorax being pale brown with a large median anterior dark area, and a long lateral dark area behind this as in *Corethra*. S. Queensland.

12. *A. bifurcatus* — abdomen with golden hairs, thorax with two broad bare lines in front. Europe.

13. *A. algeriensis* — abdomen with brown hairs, lateral scales of veins longer and finer than in *A. bifurcatus*. Anterior and posterior cross veins in same line in both sexes. In *A. bifurcatus* the posterior is internal in female, the anterior in male. Africa.

14. *A. barberi* — differs from previous two in having stalk of first fork cell equal to instead of greater than one third length of cell. The larva lives in holes in trees. Maryland, U. S. A.

aaaaa. Wings unspotted, legs unbanded, thorax with normal pattern, second fork cell exceeds half length of first, palpi banded.

15. *A. smithi* — Wing scales very dense. Sierra Leone.

16. *A. nigripes* — Not so dense as in previous species. Thorax, gray markings. Europe, America.

aaaaaa. Wings unspotted, legs unbanded, thorax with normal pattern, second fork cell does not exceed half the length of the first.

17. *A. aitkeni.* Bombay presidency.

aaaaaaa. Wings unspotted, legs banded.

18. *A. lindesayi* — A dark species. Costa, black, apical white spot; hind femora with characteristic broad white band. Hill species chiefly. India.

19. *A. immaculatus* — An ash-gray species. Slight apical bandings to tarsi. Palpi and proboscis lighter at apex. A very rare species. Ennur, Madras.

Subfamily Megarhininæ

Table of Genera

a. Palpi 5-jointed in female (long) Genus *Megarhina*
b. Palpi 3-jointed in female (comparatively short) Genus *Toxorhynchites*

Subfamily Culicinæ

Table of Genera

a. Legs more or less densely scaled.
Posterior cross vein nearer the base than the mid cross vein; hind legs with tarsi in male densely long scaled; wing scales long and rather thick Genus *Eretmapodites*
Cross vein as in Culex; scales of crown and occiput broadly spindle-shaped; 3d long vein continued as distinct pseudovein into the basal cell Genus *Janthinosoma*
Posterior cross vein nearer base of wing than mid cross vein; wings with thin scales . . . . Genus *Psorophora*
Posterior cross vein nearer apex of wing than mid cross vein; wings with large pyriform parti-colored scales . . . . Genus *Muscidus*
aa. Legs uniformly clothed with flat scales.
Scales of the wings very large, flat, broad, asymmetrical Genus *Panoplites*
Scales of wings dense, lateral ones large, elongated oval or lanceolate Genus *Tæniorhynchus*
Metanotum nude, scales of wings much as in *Tæniorhynchus*, metanotum with a tuft of chetæ and with patches of flat scales Genus *Trichoprosopon*
b. Head and scutellar scales all flat and broad.
Third long vein as an incrassation into the basal cell Genus *Armigeres*
bb. Nape clothed with mixed narrow, curved, and upright forked scales, with small lateral patches of flat scales.
Second antennal joint small or moderate-sized
Scales of the wings small, lateral ones linear . . . . Genus *Culex*
Second antennal joint very long, distal joints without scales Genus *Deinokerides*
Second antennal joint very long, 2d to 5th joints clothed with scales Genus *Brachiomyia*

Subfamily Ædinæ

Table of Genera

A. Proboscis formed for piercing; metanotum nude.
a. Palpi three to five jointed. Body showing generally a distinct metallic luster. One or more of the legs provided with a paddle-shaped expan-

sion, formed of elongated scales, "3" nearer apex of wing than "4"; "2" nearer apex than "3"; III extended into basal cell Genus *Sabethes*

b. Palpi two or three jointed; non-metallic.
Wing scales large and flat, and bracket-shaped; fork cells normal *Genus Ædomyia*
Wing scales small, linear like Culex; fork cells normal *Genus Ædes*

c. Palpi five-jointed; fork cells normal; metallic *Genus Hæmagogus*

d. Palpi two-jointed; fork cells very small; with metallic spots of flat scales on the thorax and elsewhere . . . . *Genus Uranotænia*

B. Proboscis formed for piercing; metanotum armed with chetæ: palpi small.
Proboscis rather or very long . . . . *Genus Wyeomyia*

A convenient key for the identification of eggs, larvæ and pupæ may be found in *Mosquito Life* by Mitchell,[1] pp. 216–258.

[1] Mitchell, Evelyn G., 1907. Mosquito Life. G. P. Putnam's Sons, N. Y., pp. xxii + 281.

CHAPTER X

MOSQUITOES AS DISEASE BEARERS

A. Malaria

Malaria. — Malaria is a widely distributed disease, prevalent to a greater or less degree on every continent. While not restricted to the lowlands, it does not occur extensively at high altitudes, primarily because of the lower temperature, *i.e.* the disease requires an average summer temperature of not less than 60° F. There are, however, situations in which it is known to occur at an elevation of 3000 feet, notably in Java and Madagascar.

Malaria is also commonly known as ague, chills and fever, intermittent fever, remittent fever, jungle fever, paludism, etc. The symptoms, even though slight, are usually manifested in the form of a regularly appearing paroxysm consisting of three fairly well-defined stages, viz.: the *cold stage* (the chill) in which the skin becomes pale and has the appearance of "gooseflesh," the patient's teeth may chatter, and he may shiver more or less violently; the next stage is the *hot stage* or fever, the temperature rising during the chill, the skin is hot and flushed; the third stage is marked by the appearance of a general perspiration, the fever falls, and the patient becomes normal. The entire paroxysm may last but a few hours. In many cases the stages are not so well marked, neither do the paroxysms recur at exactly the same interval, — the latter depends largely on the type of infection.

The disease is caused by blood-inhabiting Protozoa belonging to the genus Plasmodium. These parasites attack the red corpuscles, destroying the same while reproducing asexually; this asexual reproduction or sporulation occurs at fairly regular intervals, *i.e.* twenty-four, forty-eight, or seventy-two hours, depending upon the species of Plasmodium involved, the paroxysm resulting at corresponding times. That the paroxysm is due not to the destruction of the myriads of corpuscles at a given time, but to the liberation of a toxin produced by the intracorpuscular parasites, is now generally believed.

Historical. — Malaria, though not receiving its name until the middle of the eighteenth century, has been known for many centuries, Hippocrates having divided periodic fevers into the quotidian (daily), tertian (every third day) and quartan (every fourth day). The fable of Hercules and the Hydra is believed to refer to malaria, and the disease is mentioned in the Orphic poems. The successful treatment of malaria dates back previous to the seventeenth century. The Countess del Cinchon, the wife of the Viceroy of Peru, was cured of fever in 1638 by the use of the bark from a certain tree. This bark was introduced into Europe in 1640, and in 1741 Linné named it "cinchona" in honor of the Countess del Cinchon. In 1753 Torti named the disease "malaria," believing it to be air borne and emanating from the bad air (*mal aria*) rising from swamps and marshes.

The credit for the discovery of the causative organism belongs to Laveran, a French army surgeon who was stationed in Algeria. This discovery was made in 1880. Although the mosquito transmission theory is said to have been held for many years among the Italian and Tyrolese peasants and the natives of German East Africa, the first well formulated mosquito-malaria theory was advanced by King in 1883. In 1885 Golgi discovered that the periodicity of the fevers corresponded to the periodic sporulation of the Plasmodium.

Nuttall (1899) refers to the interesting fact that the malaria-mosquito theory has been repeatedly rediscovered by writers in various countries, *e.g.* Laveran first mentioned the theory in 1891, Koch (according to Pfeiffer) in 1892, Manson in 1894, Bignami and Mendini in 1896 and Grassi in 1898.

The greatest discovery in the history of malaria (as evidenced by the fact that two Nobel prizes have been awarded the discoverer) was made by the Englishman, Major Ronald Ross, in 1898, then stationed in India. Ross demonstrated beyond doubt the important rôle played by mosquitoes in the transmission of malaria, and mankind owes no greater debt to a fellow man than this. Late in the same year Grassi proved that malaria can only be transmitted by a particular kind of mosquito, namely, Anopheles.

In 1900, at the suggestion of Sir Patrick Manson, Doctors Sambon and Low built a mosquito-proof hut in the Roman Campagna, in which they lived during the most malarial months of that year without contracting malaria. At this time these investigators sent infected Anopheles mosquitoes from the Campagna to London, where Doctor Manson's son, Dr. P. Thurburn Manson, and Mr. George Warren permitted themselves to be bitten by these mosquitoes and in due time became ill with the disease.

The use of oil as a factor in mosquito control dates back to the beginning of the nineteenth century; however, the present extensive use of kerosene for this purpose is due largely to the efforts of Howard, beginning in 1892.

While certain German investigators claimed to have reared the malaria parasite *in vitro* previously, it appears that the first recorded successful attempts to accomplish this were made by Bass in 1911.

Circumstantial Evidence. — Immediately following great spring floods when the valleys become inundated and the receding water leaves behind it innumerable pools and overflowed cellars and cesspools, there is always much more malaria than usual, a fact always predicted. Coincidentally mosquitoes are unusually abundant, and especially the noiseless kind. Exceedingly warm moist seasons always bring more malaria, while a prolonged drought is commonly said to kill the disease, as does the approach of cold weather.

A very common suggestion made to escape malaria is to keep out of the " night air " and close windows and all openings which might permit the " night air " to enter.

In localities where anti-mosquito campaigns have been waged with vigor there has quickly followed a decrease in malaria, no other precautions having been taken.

The circumstantial evidence against the mosquito (in a broad sense) may be summed up as follows:

(1) Malaria exists endemically in districts where mosquitoes are present (all species except the Anophelines are eliminated experimentally); (2) malaria does not exist endemically where there are no mosquitoes (existing cases are without exception traced to an earlier visit on the part of the patient to some locality in which mosquitoes of the Anopheline type occur); (3) persons protecting themselves against mosquito bites while dwelling in malarial districts (otherwise living as do the natives) do not contract malaria; (4) communities previously noted for malaria have been practically freed from this disease when efficient drainage (sewer) systems have been installed; (5) properly conducted mosquito crusades result in the elimination of about 50 per cent of the cases of malaria within that district in the same season. (The existing cases can be accounted for through relapses and exposure to mosquito bites outside the protected district.)

It may be said that malaria may be wholly absent in the presence of an abundance of mosquitoes. In answer to this it may be replied that there are several hundred species of mosquitoes, of which number only one or two species for any one locality are capable of transmitting malaria. Hence, first, the mosquitoes in such localities are probably all non-malaria-bearing, with the entire absence of the malaria-bearing species (Anopheline), or, secondly, if Anopheline mosquitoes are present, they have not become infected by the importation of persons affected with malaria, *i.e.* malaria must first be introduced before the Anopheline mosquitoes can carry it from person to person.

Experimental Evidence. — The parasite of malaria can easily be seen by examining microscopically properly stained blood from infected persons. The disease can be produced experimentally in healthy persons by inoculation with parasitized blood taken from a malarial patient.

Malaria is popularly believed to be present in certain sources of drinking water, also in overripe fruit. This was the case in two communities in California in which it was proposed to control the disease by combating mosquitoes. The sanitary inspectors drank this water, ate freely of the ripest fruit and were exposed to the severest heat of the day and remained free from malaria, having exercised the proper night precautions. That miasma from swamps has no direct relation to malaria was proved by Sambon and Low, as already noted.

It is well known that blood taken directly from a patient suffering from malaria may show flagellated parasites. Ross, in 1895, in his Indian observations found these flagellated bodies in the intestines of mosquitoes which had fed on the blood of malarial patients. Many experiments were made and hundreds of mosquitoes examined during the next few years by Ross. The most striking condition found in some of these mosquitoes was the development of pigmented cells in the stomach wall, the pigment corresponding to malaria pigment Some of these mosquitoes gave positive results, while the majority gave negative results. Those which furnished positive results were of a particular species, and this gave the clew that the malaria parasite required a particular species of mosquito to serve as intermediary host. The connection between the flagellated bodies and the pigmented cells was furnished by MacCallum in 1898. He found that the function of the flagellated cells was that of an impregnating body; that each flagellum, of which there were several to each cell, impregnated a spherical parasite. MacCallum's observations were made on the Proteosoma of birds, also known as "bird malaria." Using the Proteosoma as a basis for his further observations, Ross found that the pigmented cells, migrating through the stomach wall of the mosquito [1] and encysting just beneath the peritoneal lining, grew steadily for three or four days, forming spindle-shaped bodies, which were shed into the body cavity and in six or seven days after feeding were found in vast numbers in the salivary glands.

Grassi's experiments in the Roman Campagna and Sicily proved that human malaria was carried solely by Anopheline mosquitoes. According to Nuttall one of the early experiments of Grassi and Bignami was conducted somewhat as follows: Three species of mosquitoes, *Culex penicillaris, Culex malariæ* and *Anopheles claviger* were collected in a malarial district, Maccarese, 22 miles from Rome. The insects were then allowed to bite a patient (who consented to the experiment) in the Santo Spirito Hospital (Rome). The patient had never had malaria. In addition to the bites from the imported insects the man was also subjected to the bites of mosquitoes emerging from larvæ placed in the room occupied by him at night. A new supply of larvæ was placed in the room every four to six days. In due time the man acquired æstivo-autumnal malaria as evidenced by the appearance of parasites in his blood. Grassi believed that the disease was due to the bites of *Culex penicellaris* because it was the most numerous, while *Anopheles claviger*

[1] It should be noted here that certain Culicine mosquitoes (*Culex pipiens*) are the transmitters of *Proteosoma* though inefficient as transmitters of *Plasmodium* or human malaria.

was present in very small numbers. Nuttall remarks that the infection could only have been produced by the latter, as has been determined since.

After describing the conditions under which Sambon and Low lived in the Roman Campagna while experimenting with malaria, Manson[1] writes as follows: "Whilst this experiment was in progress mosquitoes fed in Rome on patients suffering from tertian malaria were forwarded in suitable cages to the London School of Tropical Medicine, and on their arrival were set to bite my son, the late Dr. P. Thurburn Manson, and Mr. George Warren. Shortly afterwards both of these gentlemen, neither of whom had been abroad or otherwise exposed to malarial influences, developed characteristic malarial fever, and malarial parasites were found in abundance in their blood, both at that time and on the occurrence of the several relapses of malarial fever from which they subsequently suffered. The mosquito-malaria theory has now, therefore, passed from the region of conjecture to that of fact."

The Parasite. — The malarial parasites (Plasmodia) belong to the lowest forms of animal life, the Protozoa (Subphylum Sporozoa, Class Telosporida, Subclass Hæmosporida). The pigment of these red-blood-corpuscle-inhabiting parasites is dark and characteristic and properly termed melanin. The presence of the parasites usually gives rise to a periodic chill and fever, due to their periodic asexual reproduction (sporulation) and the liberation of a toxin in the human blood.

To detect the presence of the parasite a drop of blood is drawn from the lobe of the patient's ear or finger tip, after proper cleansing with alcohol; the droplet of blood is lightly touched with a glass microscopical slide, upon which a film (smear) is made by gently and evenly spreading the droplet by means of a needle or edge of another slide. The film is then fixed and stained, using Romanowsky modifications, such as Wright and Leishman, also Giemsa and Jenner. If parasites are present in the blood, they should be visible after careful microscopical examination as pigmented intracorpuscular bodies in the form of signet rings, amœboid forms or as crescents in æstivo-autumnal fever of ten or more days' duration. Microscopic examination under an oil immersion lens is desirable, though crescents can easily be seen with lower powers.

The ease with which parasites can be discovered in a blood smear depends on several important factors, — first, on the length of time that the patient has had malaria, and secondly on the condition that he has lately taken quinine when the chances for the discovery of parasites is reduced practically to nil. Ross[2] states that the parasites "will not generally be numerous enough to cause illness unless there is at least

[1] Manson, Sir Patrick, 1909. Tropical Diseases. Cassell and Company (London). pp. xx + 876.

[2] Ross, Ronald, 1910. The Prevention of Malaria. E. P. Dutton & Company, New York. pp. xx + 668.

one parasite to 100,000 hæmatids; that is, 50 parasites in 1 cmm. of blood; or 150,000,000 in a man 64 kilograms in weight. . . . Such calculations demonstrate the absurdity of supposing that there are no plasmodia present in a person because we fail in finding one after a few minutes' search. As a matter of fact, even if as many as 150,000,000 plasmodia are present in an average man, the chances are that ten to fifteen minutes' search will be required for each plasmodium found; while if we are careless or unfortunate, we may have to look much longer."

The various types of malaria are due to the fact that there are several species of parasitic plasmodia, each of which produces specific

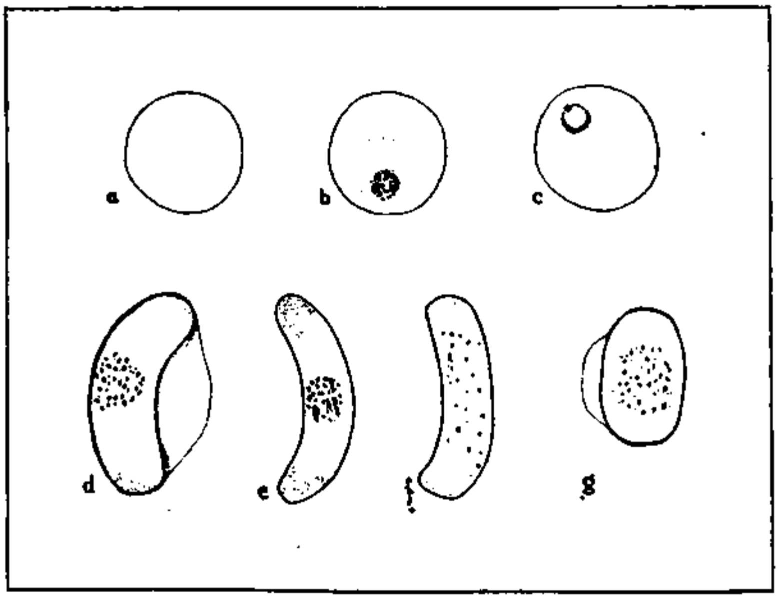


Fig. 89. — To illustrate detection of malaria parasite. *a.* normal unparasitised red blood corpuscle; *b.* young intracorpuscular parasite; *c.* signet ring; *d.* intracorpuscular crescent; *e.* free female crescent; *f.* free male or hyaline crescent; *g.* female oval.

symptoms. Three or possibly four distinct types are usually recognized: (1) *Æstivo-autumnal* or *Malignant Tertian;* (2) *Tertian* or *Benign Tertian;* (3) *Quartan,* and (4) *Quotidian.*

a. Plasmodium præcox Dofl. (*Hæmamæba præcox* Grassi et Feletti, *Plasmodium falciparum* Welch) is the cause of æstivo-autumnal fever (malignant tertian fever) of the tropics and subtropics with the paroxysm recurring every forty-eight hours. The pigment granules in this species are relatively few and very coarse. The infected red corpuscle is usually normal in size, but may be slightly shrunken and crenated. The segmenting stage, which is rarely seen in the peripheral blood, is said to produce only from eight to ten merozoites, according to Stephens and Christophers, or from five to twenty-five and over according to Deaderick. Characteristic crescents (Fig. 89) or gametocytes (immature sexual forms) are commonly observed in cases of ten or more days' duration. Crescents occur in this species only. The female crescents show the chromatin granules well concentrated in the mid-region, with slight stippling at both ends, while the male crescents have the chromatin thinly scattered with both ends hyaline (they are also called hyaline bodies or hyaline crescents). Certain relapses after months of latency are said to be traceable to a parthenogenetic cycle, in which the female crescents produce merozoites asexually, which now attack the red blood corpuscles, as do the ordinary sporulated forms. Sporulation occurs about every forty-eight hours.

b. Plasmodium vivax Grassi et Feletti (*Hæmamæba vivax* Grassi et Feletti) is the cause of tertian fever or benign tertian malaria of temper-

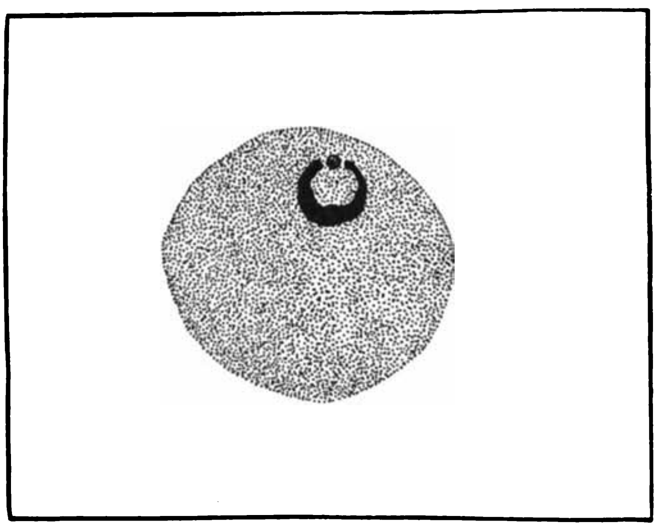


FIG. 90. — Signet ring stage of malaria parasite.

ate climates, occurs also abundantly in the tropics and subtropics, with recurrent paroxysms regularly every forty-eight hours. In these parasites the pigment granules are very fine and are distributed throughout the red corpuscles as Schüffner's dots. The parasitized corpuscles are distinctly enlarged and are quite pale. The parasites are bizarre in form. There are no crescents in this species, and the gametocytes are not easily distinguishable from the asexual parasites, except for their more regular form and denser pigmentation. The number of elements in the sporulating or segmented stage commonly seen in the peripheral blood is larger than in the former, and their arrangement is irregular (fifteen or more, according to Stephens and Christophers). Sporulation occurs regularly every forty-eight hours.

c. Plasmodium malariæ Laveran (*Laverania malariæ* Grassi et Feletti, *Hæmamæba malariæ* Grassi et Feletti) is the cause of quartan fever, with recurrent paroxysms every seventy-two hours. This form of malaria is comparatively rare, and coincides in distribution with æstivo-autumnal fever. The pigment is coarse and generally occurs in marginal streaks or in bands. The parasitized corpuscles are usually normal in size, and the parasite is more or less oval in shape. The gametocytes are rarely seen. The segmenting stage gives rise to the typical "daisy" form, each sporulated body radiating from the center. The number of bodies varies from six to twelve, oftenest eight (Deaderick). Sporulation occurs every seventy-two hours.

d. Plasmodium falciparum quotidianum Craig is believed to be the causative organism of quotidian malaria, with paroxysms recurring every twenty-four hours. This must not be confused with multiple infection on the part of other species of Plasmodia which might also result in daily paroxysms. This type of malaria occurs in practically all parts in which æstivo-autumnal fever occurs. The parasite resembles *Plasmodium præcox* (= *P. falciparum*) very closely, but the infected corpuscles are said to be considerably smaller than normal, and are usually brassy in appearance.

The *signet ring* (Fig. 90) is the earliest stage in the development of the intracorpuscular parasite of all species, and is characterized by a blue staining ring with a heavy chromatin dot (the nucleus) at or near the thinner segment. The thickness of the wider segment varies with the species, *e.g.* in the large conspicuous rings of both *P. vivax* and *P. malariæ*, the rings are quite thick and the dot is usually situated in a line with the thinner segment; in *P. præcox* the rings are smaller and thinner and the chromatin dot (commonly double) is frequently out of line with the ring. There may be two and even three rings inside of one corpuscle.

Life History of the Plasmodium. — The life history of malaria Plasmodia involves two distinct cycles; namely, first, the *asexual*, also known as the human cycle, cycle of Golgi or schizogonic cycle; and secondly, the *sexual*, also known as the mosquito cycle, cycle of Ross or sporogonic cycle. A third cycle which explains the recurrence of malaria after longer periods of latency is known as the *parthenogenetic* or virgin cycle, passed within the human body.

The *asexual cycle* (Fig. 91, 1–6), passed within the blood of the human, begins with the introduction of spindle-shaped *sporozoites* injected into the circulation with the bite of the Anopheles mosquito. Each sporozoite not captured by phagocytes at once bores into a red cell, where it quickly goes into the *signet ring* stage, growing rapidly until the corpuscle is more or less filled depending upon the species of parasite, and is then known as a *merocyte*. The full-grown merocyte now divides into a larger or smaller number of bodies (also depending upon the species) which are then liberated, being now free in the plasma and

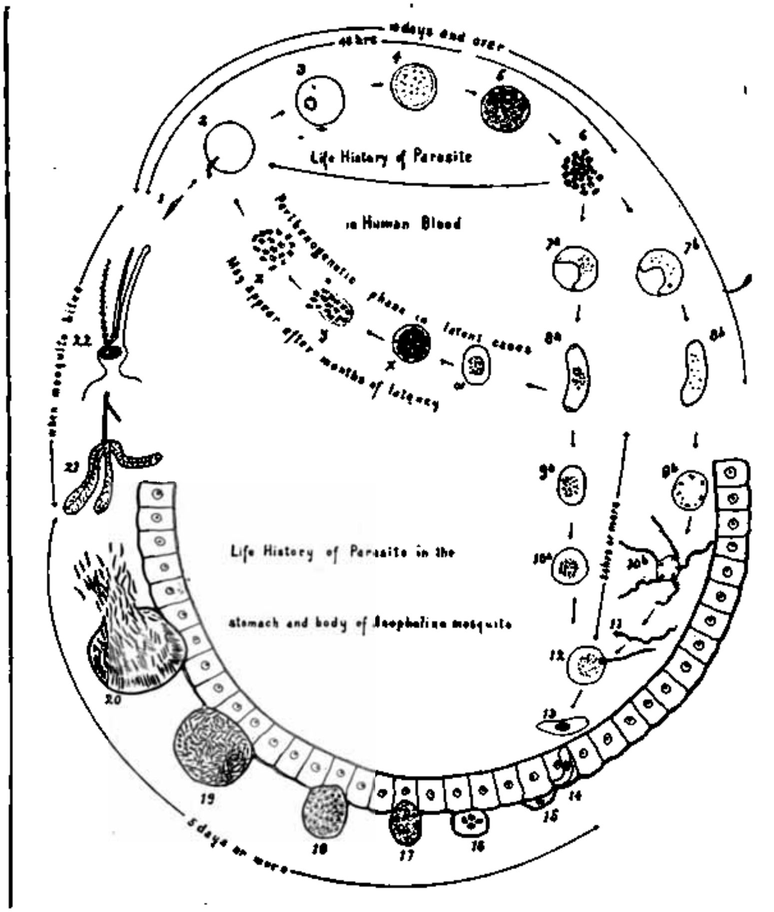


FIG. 91. — Diagram to show life history of parasite (*Plasmodium præcox*) of æstivo-autumnal malaria. 1–6, asexual or schizogonic cycle in human blood, requiring 48 hours to complete (72 hours in quartan); 1, represents a vermicule or sporozoite, either in salivary gland of mosquito or newly injected into human circulation; 2, represents a red blood corpuscle about to be parasitized by a sporozoite; 3, shows a young parasite in signet ring form; 4, fully grown parasite with dividing nucleus; 5, shows parasite sporulated, but still intracorpuscular; 6, sporulation, each body a merozoite ready to enter a new corpuscle; some are sexual and may develop into gametes; 7*a*, female gametocyte, still intracorpuscular; 7*b*, male gametocyte, also intracorpuscular; 8*a*, free female crescent, which may sporulate, producing a parthenogenetic cycle (*w*, *x*, *y*, *z*); 8*b*, male gametocyte or hyaline crescent (crescents do not ordinarily appear in the blood until ten days or more after infection); 9–20 illustrates the sporogonic or sexual cycle of the parasite within the body of a female Anopheline mosquito, requiring six to ten days and over to complete; 9*a*, 9*b*, female and male gametocytes in stomach cavity of mosquito; 10*a*, female gamete (macrogamete); 10*b*, exflagellated male gametocyte; 11, deflagellated male gamete (microgamete); 12, fertilization; (9–13 requires about 24 hours.) 13, oökinete or zygote ready to penetrate stomach; 14, oökinete burrowing through stomach wall; 15, oökinete outside of stomach wall and inside peritoneal lining, forming characteristic cyst, growing progressively larger. (16–19) in which the parasite sporulates, forming the sporozoites; 20 shows sporozoites (vermicules) escaping from cyst and migrating forward to salivary glands (21); (14–20 requires five days or more.) 21, salivary glands of female mosquito; 22, head of female Anopheles. (Original, with suggestions from Grassi and Schaudinn in Mense's *Handbuch*.)

are known as *merozoites*. The time required for this sporulation is from twenty-four to seventy-two hours according to the species. Each merozoite now enters another adjacent red cell and again the cycle repeats until the infection is great enough to produce a paroxysm, *i.e.* in from six to twelve days, commonly about ten days.

The great majority of the merozoites are asexual, but some of them are potential males and females, which require a longer time, probably not less than ten days, to develop to their full growth, then known as *gametocytes*. In *Plasmodium vivax*, the sexual forms are not easily recognized; however, the following characters are useful: "(1) their larger size, (2) more abundant pigment, (3) there is usually only one fairly large chromatin mass, whereas in an asexual form of nearly equal size the chromatin has already begun to divide into several portions (segmenting stage)" (Stephens and Christophers). In *P. praecox* the sexual individuals are in the form of crescents. The female crescent (*macrogametocyte*) has the pigment collected at the center (Fig. 89*e*), while the male crescent (*microgametocyte*) has the pigment scattered throughout and is known as a hyaline crescent (Fig. 89*f*).

With the complete development of the gametocytes all is ready for the next cycle (the sexual) which can only be undergone within the body of an Anopheline mosquito. In the meantime the asexual cycle is repeated over and over, unless quinine is taken to destroy the parasites, or until senescence occurs. The gametocytes are not thus easily destroyed, persisting in the body for long periods of time, and may, under certain conditions, result in relapses, without reinfection by mosquitoes, which relapse is traceable to a parthenogenetic cycle of the female (Fig. 91 *w*, *x*, *y*, *z*). But for this phenomenon, which may, of course, fail to occur, a person eventually becomes rid of malaria, provided he avoids reinfection by mosquitoes through removal from a malarial locality, because of the senescence which naturally results from continued sporulation without sexual intervention or rejuvenation in the mosquito. It is believed that this senescence or eventual dying off of the non-sexual forms is due to the toxin produced by these organisms reacting upon themselves.

Hence it becomes clear that the sexual cycle is necessary to the life of the species. It is a well-known fact that the male gametocyte extrudes flagella when malarial blood is exposed to the air, as when in contact with a glass slide. The parasites when thus taken from their normal habitat invariably die within a few minutes, unless a special medium is employed; *e.g.* that devised by Bass in which the asexual cycle may be observed outside the human body.

Sexual development, the cycle of Ross (Fig. 91, 9–22) has only been observed in the female Anopheline mosquito; in the stomach of this insect flagellation of the male gametocyte takes place. After a peripheral arrangement of the chromatin (in clumps corresponding to the number of flagella) there are extruded from three to six long slender filaments (flagella), each of which breaks loose from the parent body (exflagellation), forming the male *gamete* (*microgamete*) corresponding in function to the spermatozoön of higher animals. The female gametocyte, now known as the *macrogamete,* having been taken into the stomach of the mosquito with the microgametocytes in the act of sucking blood, now also undergoes certain changes, becoming rounded or oval in form with the chromatin mass centrally located. In this condition, still in the stomach of the mosquito, the microgamete penetrates, *i.e.* fertilizes the macrogamete, producing the oökinete, in which stage the wall of the stomach is penetrated and a position is taken up just beneath the membrane forming the outer stomach lining. In this position the parasite grows enormously, forming a cyst (Fig. 91, 15–19) in which many nuclei appear in from four to five days. These tiny nucleated bodies give rise to hundreds of spindle-shaped organisms (*sporozoites*) which are in from twenty-four to forty-eight hours more shed into the body cavity of the mosquito. The sporozoites eventually collect in the salivary glands, remaining there until the mosquito bites again, when many of them may be injected with the saliva into the wound. The time required for the completion of the sexual cycle varies from seven to ten days under favorable conditions, *i.e.* an average temperature of not less than 60° F. Once infected the mosquito probably remains infected for the rest of its life.

With the introduction of the sporozoites into the blood of the next victim the asexual cycle begins as already explained.

Time Factor. — Although there are some localities in which nearly all the inhabitants are infected with malaria, newcomers or visitors may or may not soon fall a prey to the disease, for the reason that not more than 25 to 35 per cent of the Anopheles mosquitoes are infected during the height of the season and correspondingly fewer early in the spring. This is dependent upon both the time when the infected person and the next victim are bitten. Obviously the mosquito cannot transmit malaria when there is none present to be transmitted; again, the sexual parasites (gametocytes) must be in the peripheral circulation when the mosquito bites the infected individual; and again after the mosquito becomes infected a period of not less than six days (possibly five in benign tertian, and twelve days in æstivo-autumnal) must elapse before a new victim can be inoculated, *i.e.* the time required for the sexual development of the parasite. This incubation period may be prolonged through reduced temperature, with apparently no development in low temperatures (according to Manson this phase of the malaria parasite requires a "sustained average temperature of at least 60° F."). Thus it becomes evident that the time factor plays an important rôle in the spread of malaria.

Is Malaria Inherited by Mosquitoes? — For the reason that malaria is said at times to be contracted by explorers who have entered uninhabited territory it is believed by some that the mosquitoes of said territory had become infected perhaps years ago and that the parasite has been handed down from generation to generation from the female to the ovum, ovum to larva and thus through the mosquito cycle. The fact that Texas fever is thus inherited and infection is brought about by the seed tick seems to lend weight to the argument. To test this matter larvæ of *Anopheles quadrimaculatus* were brought by the writer from an intensely malarial district to Berkeley and the adults reared from these were permitted to bite healthy students, and in no case did infection result.

Knowing the life history of the parasite it would be more reasonable to assume that other warm-blooded animals besides man harbor the protozoön during its asexual cycle, but numerous and convincing experiments, in which monkeys, horses, dogs, cats, rabbits, pigeons, owls, etc., also frogs and turtles were used, negate this assumption.

The explanation is probably to be found in the fact that such individuals must necessarily pass through malarial districts while on their way to uninhabited territory. Infection might easily result, but the malaria symptoms do not appear until the destination is reached. The time factor and exposure, no doubt, explain the phenomenon.

Anopheline Species Concerned. — Although no Anopheline mosquito should be trusted, there are comparatively few species which are experimentally known to be carriers of malaria. *Anopheles quadrimaculatus* Say and *A. crucians* Wied. are the most dangerous North American species. While *A. punctipennis* Say may be very abundant in certain localities, malaria may be rare or absent. *Anopheles maculipennis* Meig. is the most important European species; *A. albimanus* Wied. and *A.* (*Cellia*) *argyrotarsis* Rob. are the most important species for Central America. Moreover it has been found that not all species of malaria parasites can be carried equally well by the same species of Anopheles, *e.g. A. crucians* is said to be the most important carrier of æstivo-autumnal fever but is negative to other forms.

Several other genera of Anopheline mosquitoes (Asiatic and African) include malaria-bearing species, among them Cellia, Nyssorhynchus, *e.g. N. fuliginosus* Giles of India and the Philippines, Myzorhynchus, *e.g. M. sinensis,* Wied. of China and the Philippines, and Myzomyia, *e.g. Myzomyia minimus* Theo. of the Philippines. The aforementioned genera are all to be included in the genus Anopheles.

How Does the Malaria Parasite Overwinter? — Since malaria has a typical seasonal occurrence, with little or no appearance during the winter months, the question arises, does the parasite overwinter in its human host to break out in the spring in individual cases by the process of parthenogenesis, or does it overwinter in the body of the mosquito? The weight of evidence is against the latter possibility. The writer believes that the Anopheles mosquito seldom or ever takes a suck of blood before going into hibernation. A suck of blood would militate against the life of the mosquito inasmuch as it causes the development and ultimate extrusion of ova and that terminates the life of the insect. Other physiological reasons involving further increased metabolism seem to discount the possibility of successful hibernation. Furthermore the writer has seen great numbers of voracious Anopheles in the spring both indoors and out, and has been frequently bitten by these as have many others without becoming infected. These hibernated individuals on coming out early in the spring bite viciously even at noonday. Furthermore evidence that infected mosquitoes exist during the winter months seems to be lacking or has been overlooked.

On the other hand latent human infection has been amply proved and this may easily lead to the infection of the mosquitoes appearing in the early spring and thus lead to the spread of malaria as the season advances.

B. Yellow Fever

Yellow Fever. — Yellow fever is a disease peculiarly restricted to the tropics, being endemic in the West Indies, spreading thence northward into the southern United States and westward into Panama, central America, Mexico, the west coast of South America and parts of Africa. The disease is marked by a rapidly increasing fever, headache and backache, and in most cases followed in three or four days by a yellow coloring of the skin (whence the specific name) and a characteristic black vomit.

A Mosquito the Carrier. — Finlay of Havana in 1881 was the first to advance the mosquito transmission theory, though Nott (according to Nuttall) as early as 1848 attributed it to the higher insects. Though the former carried on what is now known to have been incriminating experiments with mosquitoes on non-immunes, his theory was discredited, until Sternberg, Surgeon General of the United States Army, became interested in his (Finlay's) theory, made stronger through the malaria discoveries, and established a commission in 1900 to study the yellow-fever-mosquito theory in Cuba. The commission consisted of Doctors Walter Reed, James Carroll, Jesse W. Lazear and Aristides Agramonte, and of these Doctors Carroll and Lazear contracted the disease during the progress of the investigation, the latter succumbing to the attack. In the autumn a field station was established named Camp Lazear in honor of the deceased investigator. The camp was systematically arranged for the most accurate observations and experiments. Two small buildings were erected, one of which was used to determine whether yellow fever can be transmitted through contact with soiled articles of dress and bedding, ventilation being purposely poorly provided for, the only precaution being the exclusion of mosquitoes. The second building consisted of two rooms, with thorough ventilation and disinfection; one room was kept free from mosquitoes, while into the other were introduced mosquitoes which had previously bitten yellow fever patients. In all cases the individuals experimented on were non-immunes. In the first case, those exposed to fomites, none became infected, though the experiment lasted over two months. In the second case, those individuals occupying the mosquito-protected room did not become diseased, while six out of the seven occupying the room into which mosquitoes were introduced became ill with yellow fever. The following conclusions were reached by the commission:

"1. The mosquito — *C. fasciatus* (later known as *Stegomyia calopus*, now *Ædes calopus*) serves as the intermediary host for the parasite of yellow fever..

2. Yellow fever is transmitted to the non-immune individual by means of the bite of the mosquito that has previously fed on the blood of those sick with this disease.

3. An interval of about twelve days or more after contamination appears to be necessary before the mosquito is capable of conveying the infection.

4. The bite of the mosquito at an earlier period after contamination does not appear to confer any immunity against a subsequent attack.

5. Yellow fever can also be experimentally produced by the subcutaneous injection of blood taken from the general circulation during the first and second days of this disease.

6. An attack of yellow fever, produced by the bite of the mosquito, confers immunity against the subsequent injection of the blood of an individual suffering from the non-experimental form of this disease.

7. The period of incubation in thirteen cases of experimental yellow fever has varied from forty-one hours to five days and seventeen hours.

8. Yellow fever is not conveyed by fomites, and hence disinfection of articles of clothing, bedding, or merchandise, supposedly contaminated by contact with those sick with this disease, is unnecessary.

9. A house may be said to be infected with yellow fever only when there are present within its walls contaminated mosquitoes capable of conveying the parasite of this disease.

10. The spread of yellow fever can be most effectively controlled by measures directed to the destruction of mosquitoes and the protection of the sick against the bites of these insects.

11. While the mode of propagation of yellow fever has now been definitely determined, the specific cause of this disease remains to be discovered."

Etiology. — The work of the Yellow Fever Commission proved beyond doubt that the causative agent of yellow fever is blood inhabiting, is a filterable virus and is not traceable to *Bacillus icteroides* of Sanarelli (1897). The behavior of the disease indicates that it is of protozoal nature, perhaps closely related to malaria, but all careful research thus far put forth has failed to reveal an organism. Seidelin (1909) believed it to be *Paraplasma flavigenum*, but this is strongly denied by other workers.

Time Factor. — Since the yellow fever mosquito is both diurnal and nocturnal early in its adult history, it seems that the virus could be conveyed at any time of the day or night; this is, however, not true, as evidenced by the following observations: first, a lapse of at least twelve days is required before the bite of the mosquito becomes infective; second, after once having fed and deposited her eggs (three days later) the mosquito becomes nocturnal in habit. Therefore the day-flying individuals are too young to harbor the infective virus of yellow fever.

Another important factor to be considered is that the *Stegomyia* can only become infected by feeding on a Yellow Fever patient during the first three days of his sickness.

As in malaria, infective blood from a yellow fever patient loses its virulence on exposure to air, — "virulent blood serum lost its virulence in forty-eight hours, if exposed to the air at 24° to 30° C." (Marchoux and Simond).

C. Filariasis

Filariasis. — Filariasis is a disease of the lymphatic system produced by nematode worms of the genus Filaria. It is manifested by a swelling, often to enormous proportions, of the lower extremities, commonly the scrotum. In its more pronounced and advanced stages it commonly causes *elephantiasis*, although in this stage the filariæ may not be present.

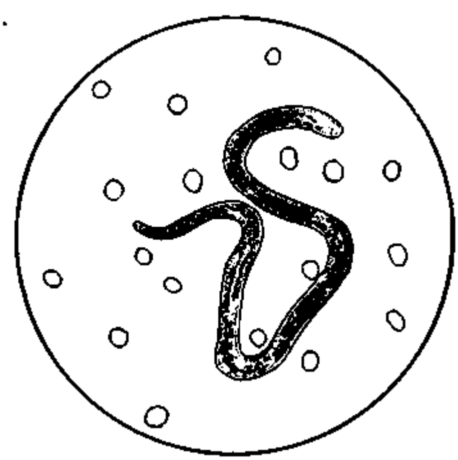


Fig. 92. — *Microfilaria bancrofti*, in human blood. × 333.

Filariasis and elephantiasis are comparatively common in the tropics and occur also in certain subtropical regions; according to Manson[1] about every second individual in Samoa is thus afflicted.

While the absence of specific filarial poisons, which might produce the disease, has not been disproven, it is said that the swellings are produced by occlusion of the lymphatics on the part of the nematodes.

The Parasite. — Although there are several blood-inhabiting worms belonging to the family Filariidæ, only one species seems to be of any great pathological importance, namely *Microfilaria bancrofti* Cobbold (*Filaria sanguinis hominis* Lewis), a tropical and subtropical species.

Microfilaria bancrofti, which is the larval form of *Filaria bancrofti,* inhabits the blood plasma, is a very slender worm, about the diameter

[1] Manson, Sir Patrick, 1909 (*loc. cit.*).

of a red blood corpuscle and is about .3 mm. in length (Fig. 92). It is inclosed in a very delicate sheath inside of which the worm has some latitude of motion both forward and backward. It is known that this parasite maintains a very striking periodicity, being abundant in the peripheral circulation only at night, beginning with the early evening and lasting until early morning with the greatest abundance at midnight, at which time Manson reports that "it is no unusual thing to find as many as three hundred, or even six hundred in every drop of blood." During the day filariæ are found in the lungs and large visceral blood vessels.

The adult filariæ, which are slender hair-like worms, inhabit the lymphatic ducts. The female parasite measures from 85 to 90 mm. in length and the male about 40 mm. (Manson). The ovoviviparous females extrude myriads of larval filariæ into the lymph sinuses which shortly thereafter swarm into the blood vessels, occupying the lungs mainly during the day and the peripheral vessels by night.

The Mosquito's Rôle in Filariasis. — Manifestly the swarming of thousands upon thousands of Microfilariæ in the peripheral blood at night offers the very best opportunity for passage into the body of nocturnal blood-sucking insects, of which the mosquito stands the best chance, owing to relative abundance and habits. The Culicine mosquitoes for some reason seem to be the most important instruments of transmission, particularly *Culex* (*fatigans*) *quinquefasciatus* Say.

Once the Microfilariæ are in the stomach of the mosquito these burst themselves free from their enclosing sheaths and proceed to migrate to the thoracic muscles, where a definite metamorphosis is undergone, resulting in a great increase in size, and the formation of a mouth and alimentary tract (Manson). This metamorphosis requires from sixteen to twenty days, depending on the temperature as do other mosquito-borne parasites. From this position the worms work their way into the ventral portions of the head and the proboscis inside the labium. From this point they enter the wound produced when the mosquito pierces the skin of its victim. Apparently the filariæ burrow directly through the membranous portion of the labella at the point of attachment to the labium. From the peripheral system the nematodes soon find their way into the lymphatics where sexual maturity occurs.

Culex (*fatigans* Wiedem.) *quinquefasciatus* Say is one of the most abundant and widely distributed species of Culicine mosquitoes of the tropics and subtropics. It is a comparatively small species (about 5 mm.) and is uniformly brown, varying from light to dark, in color. On the thorax there are situated two narrow median indistinct longitudinal lines. Apparently any stagnant fresh water, from the clearest to the vilest, affords a good breeding place for *Culex quinquefasciatus*. Stagnant, filthy gutter water seems to be especially favorable.

The entire life history, from egg to imago, is completed in about ten days under optimum conditions.

D. Dengue

Dengue, or Breakbone Fever, an epidemic, infectious, influenza-like disease of the tropics and subtropics, breaks out suddenly as an acute fever with " eruption and peculiarly severe rheumatic-like pains in the joints and limbs . . . not accompanied by pulmonary and other serious complications " (Manson). The disease is benign and of short duration.

It is caused by a filterable virus which is blood-inhabiting like yellow fever. The incubation period is said to be from two to five days.

How Transmitted. — Sufficient evidence, both experimental and circumstantial, is at hand to incriminate mosquitoes, notably *Culex quinquefasciatus* and *Ædes calopus;* and at least one reputable physician has told the writer that the control of mosquitoes during a certain dengue epidemic in the Philippines resulted in the control of the disease. Whether or not there were other factors of importance involved is, of course, a question.

E. Verruga

Verruga (*Verruca peruana*), Carrion's disease or oroya fever, occurs endemically in certain high altitudes in Peru. According to Giltner[1] the disease is characterized by fever, rheumatoid pains, anæmia and an eruption which develops into bleeding, warty tumors. It is an infectious disease of ancient origin attacking persons of both sexes and all ages. The mortality is very high in the malignant form, while in the benign form the mortality is low. The incubation period is from one to three weeks.

Causative Organism. — The causative organism of verruga has not been discovered; however, characteristic intracorpuscular bodies are present, at first believed to be parasites, and so described in the Verruga Expedition Report.[2] These bodies are known as " Bartonia bodies," or X-bodies, and are described as follows:

" *Bartonia bacilliformis.* Gen. et sp. nov. Parasites consisting of rounded or oval forms or of slender straight, curved or bent rods occurring either singly or in groups, but characteristically in chains of several segmenting organisms, sometimes swollen at one or both ends and frequently beaded. Reproduction occurs by binary division. Endowed with independent motility, moving in the direction of the long diameter, living within the red blood corpuscles of man and producing a grave form of anæmia known in Peru as Oroya fever. Stained preparations suggest differentiation of cytoplasm and nuclear material."

[1] Giltner, H. A., 1911. *Verruca peruana* or Carrion's disease. Journ. Amer. Med. Assoc., Dec. 23, 1911.

[2] Strong, R. P., Tyzzer, E. E., Brues, Charles T., Sellards, A. W., Gastiaburu, J. C., 1913. *Verruga peruviana*, Oroya fever and Uta, preliminary report of the first expedition to South America from the department of Tropical Medicine of Harvard University. Journ. Amer. Med. Asso., Vol. LXI, No. 19.

Mode of Transmission. — The first experimental transmission of verruga was accomplished by Townsend [1] in Peru, the agent having been *Phlebotomus verrucarum* (Townsend) and the animal experimented on was a hairless dog. The incubation period in this animal was about six days, *i.e.* on July 11, 1913, 1 cc. "of artificial serum containing the triturated bodies of twenty females of the Phlebotomus, collected on the night of July 9–10 in Verruga Canyon" was injected subcutaneously

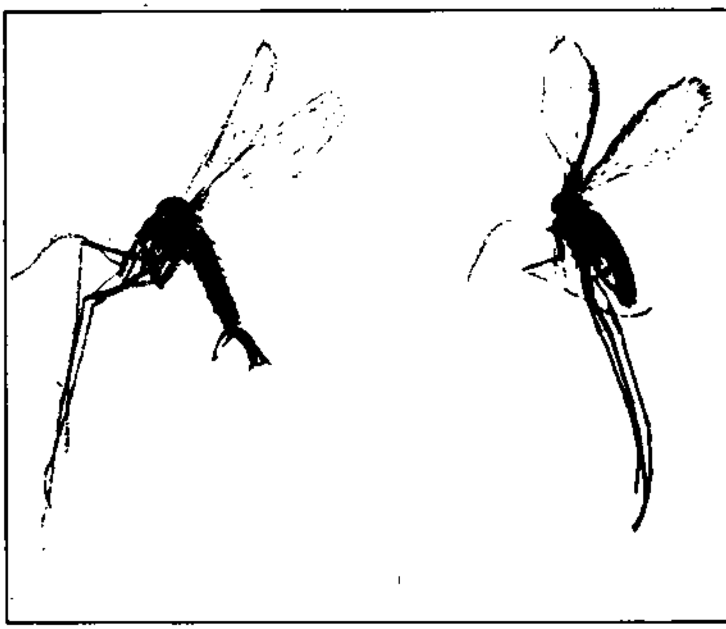


FIG. 93. — Phlebotomus or sand fly (male, left; female, right). Carrier of three-day fever. Other species transmit Papatici fever and Verruga. × 8.

in the right shoulder of the dog, and on July 17 the typical eruption began to appear.

The same author [2] later reports a human case in which the infection was undoubtedly introduced by the *bites* of Phlebotomus ("fifty-five unmistakable Phlebotomus bites on the backs of his hands and wrists") received September 17, 1913, X-bodies appearing October 1, but "no clinical symptoms other than a headache or slight feverishness at times, until October 25, when a decided rise of temperature occurred and the X-bodies were found to be much increased in number."

Phlebotomus Flies. — The Phlebotomus flies (Fig. 93) belong to the family Psychodidæ of the order Diptera, commonly known as "owl

[1] Townsend, Charles H. T., 1913. The Transmission of Verruga by Phlebotomus. Journ. Amer. Med. Assoc., Vol. XIV, No. 19.
[2] Townsend, Charles H. T., 1913. Human case of Verruga directly traceable to *Phlebotomus verrucarum*. Entomological News, Vol. XXV, No. 1.

midges," thickly haired moth-like flies of small size (3–4 mm. long). The wings are ovate in shape with heavy, almost exclusively longitudinal veins. The wings are densely hairy and fold roof-like over the abdomen. The habits of the Phlebotomus flies are described by several authors, among them Townsend,[1] who says that the tiny blood-sucking gnats "avoid wind and sun and full daylight. They appear only after sunset, and only then in the absence of wind. They enter dwellings if not too brightly lighted, but are not natural frequenters of human habitations. They breed in caves, rock interstices, stone embankments, walls, even in excavated rock and earth materials. . . . They hide by day in similar places or in shelter of rank vegetation. Deep canyons, free from wind and dimly lighted, are especially adapted to them. Thick vegetation protects them from what wind there is by day or night. . . . The flies suck the blood of almost any warm-blooded animal, and even that of lizards in at least one known case. Thus they are quite independent of man, and this accords with the verruga reservoir being located in the native fauna."

The life history of *Phlebotomus papatasii* (related to "Papatici Fever," a benign dengue-like disease) is said by Marett[2] to require about three months, — egg stage, six to nine days; larval stage, about eight weeks; and pupal stage, from eleven to sixteen days.

Marett also suggests the following prophylactic measures, viz.: "facing of walls, the removal of heaps of stones and the blocking of all holes which might serve as shelter places for the flies; also covering the ventilators with fine-meshed wire gauze, and the cleaning of all rough, made ground from weeds, so that all holes may be discovered and filled up with beaten earth. The encouragement of gardening on such grounds is, he thinks, also desirable. Large embankments should be planted with native aromatic plants such as thyme, pennyroyal, etc., and kept well earthed."

[1] Townsend, Charles H. T., 1913. A Phlebotomus, the practically certain carrier of verruga. Science, N. S., Vol. XXXVIII, No. 971.

[2] Marett, Capt. P. J., 1913. The Phlebotomus Flies of the Maltese Islands. R. A. M. C. Journ. XX, No. 2, pp. 162–171. (Abstract in *The Review of Applied Entomology*, Vol. 1, Ser. B. Part 2, pp. 27–29.)

CHAPTER XI

MOSQUITO CONTROL

Where Mosquitoes Breed. — As has already been pointed out, water is absolutely essential for mosquito breeding, though the situation varies somewhat for the species. Places suitable for Culicine mosquitoes are not always suitable for the Anopheles, but generally where the latter is found the former may also occur. The Culicine female will deposit her eggs even in the smallest receptacles containing water, such as broken gourds, tin cans, tubs, barrels, etc. (Fig. 94). It should be noted here

FIG. 94. — Tin cans, tubs and barrels in which water may stand and breed mosquitoes.

that running water is not a favorable breeding place for several obvious reasons illustrated in the life history already discussed. However, a running stream should be " edged up " so that no little coves are formed in which the water remains comparatively quiet. This applies also to gutters (Fig. 95) and irrigation ditches.

The most favorable places for the propagation of Anopheles are overflowed areas in which the water is shallow enough to allow grass and other low vegetation to be barely covered or slightly protruding (Fig. 96); such conditions are often produced by breaks in irrigation ditches, leaking water supply pipes, " leaky " hydrants (Fig. 97) and improperly channeled creeks. Marshy areas, in which the water is just below the surface, are made dangerous through the hoof marks of cattle and horses The writer has found that places, which the casual observer considers highly dangerous, are often quite harmless. Reservoirs, dredger ponds, and sluggish streams are often regarded with the keenest disfavor, though examination may indicate the entire absence of larvæ. A badly kept basin or reservoir may, however, prove a menace due to the growth of vegetation along the edges and to the shallow condition of the water. A clean pond with sharp, deeply cut banks need not be a menace as a mosquito breeder, especially when stocked with surface-feeding fishes.

Fig. 95. — Stagnant water in gutters breeds numerous mosquitoes, often Anopheles.

A receding stream (Fig. 98) often leaves shallow ponds along its banks. These very frequently become most suitable breeding places for mosquitoes, especially Anopheles. The construction of railroads and highways frequently results in obstructing natural drainage, thus causing water to stand.

It would hardly seem possible for wrigglers to develop in soap and lye laden pools from laundries, but such is nevertheless frequently the case, even for Anopheles. Cesspools also often prove a serious menace.

Essentials of Control. — In our study of the life history of the mosquito we have seen that standing water (or at least very sluggish water) is absolutely necessary for the propagation of mosquitoes; therefore, the essentials of control are at once evident, namely, the drainage of the water or its protection mechanically to prevent the adult female from depositing her eggs thereon or the application of chemicals to destroy the larvæ and pupæ. Manifestly this calls for either temporary or permanent control. Temporary control consists in the application of some insecticide to the water, such as kerosene, nicotine, phinotas oil or salt (in the case of fresh-water species under certain conditions). This method requires more or less constant repetition, and involves repeated expenditure of time, labor and money, but is extremely useful and really essential during the time that the permanent work is being advanced, in that wrigglers and tumblers, which have already made their appearance, are destroyed.

For the permanent control of mosquitoes, especially the Anopheles, the best method, by all odds, is drainage, correction of irrigation defects, cutting deeper channels where the water spreads, etc. Thirty minutes' labor in cutting a ditch deeper, or digging a new one for a short distance, has very often eliminated a nuisance that has bred malaria mosquitoes season after season.

Fig. 96. — An ideal Anopheles breeding place. The water is shallow and clear, with much vegetation. Also shows use of knapsack spray pump.

It is highly important that control efforts should be systematic and thorough. Haphazard, slipshod work only results in dissatisfaction and new crops of mosquitoes.

Oiling Methods. — As has already been explained, mosquito wrigglers and tumblers must come to the surface of the water for air, hence any material that will form an effective film over the surface of the water will serve to suffocate them. For this purpose kerosene has been found to be the cheapest and at the same time most available material. After a coat of oil has been applied the previously disturbed wrigglers and tumblers may be seen to rise and touch the under side of the oil film and successively try place after place for a point of emergence. Death from suffocation follows in from three to fifteen minutes. The same results can be secured by placing wrigglers and tumblers in a vessel of water and agitating violently for a few minutes so that the insects cannot come to the surface to breathe.

Kind of Oil. — The most desirable oil for mosquito control is one that will spread most readily without breaking up into patches and that will remain on the water for the longest time in an effective condition. Crude oil, it will be seen, breaks up into patches between which the water is not affected. Wrigglers have been found by the writer developing in such situations in localities where oil had been applied liberally. Several very prominent fiascos have been made in attempting thus to control mosquitoes. Crude oil furthermore cannot be used well in ordinary spray pumps. The lasting quality is, however, very good. Kerosene spreads most satisfactorily and does its work quickly, but evaporates in a comparatively short time, thus requiring frequent repetition. A mixture of the two can very well be made which will bring about more nearly the desired results. Our best results have been obtained with a mixture of approximately equal parts of crude oil and kerosene, though the proportion may perhaps safely range to three parts of the former to one of the latter. We have also used successfully a treated stove oil of about 28° Beaumé.

FIG. 97. — The leaking faucet with the resulting pool of water is often a constant menace in the entire absence of other mosquito-breeding sources.

Oil purchased on the market as "crude oil" varies from 12° to 18° Beaumé, while "stove distillate" varies from 28° to 32°, and water-white kerosene from 40° to 42°. Knowing the specific gravity of the oil purchased, it can easily be calculated how to mix with lighter or heavier oil in order to obtain the required consistency. Thus if kerosene (42°) is at hand and crude oil (15°), use about ten gallons of the former to twelve gallons of the latter. For spring and autumn, 28° to 30° Beaumé is to be recommended, while for summer use a heavier oil at about 26° is preferable. To mix the oils it is necessary to use the spray pump, *i.e.* repeatedly fill the chamber with oil in proper proportions, introducing the nozzle end of the hose, and churn a few minutes.

How to Apply Oil. — Simply pouring on the oil with a dipper is wasteful and requires some little time if all the smaller adjacent pools of water are to be treated. Experience has taught that the small, apparently insignificant pools of water are in reality the greatest menace and are commonly overlooked. The use of a knapsack spray pump (Figs. 96 and 99) of five-gallon capacity is highly recommended. This can be strapped on the back and will provide enough oil for twenty minutes' continuous spraying or one or two hours of ordinary oiling. Where it is out of the question to use a horse and cart to carry the oil, the field man can save himself many steps and some embarrassment if he will make it a habit to carry a small quantity of oil with him at all times in a pint or quart tin to which is attached a rubber bulb and a spray spout. The inspector usually devotes a day or

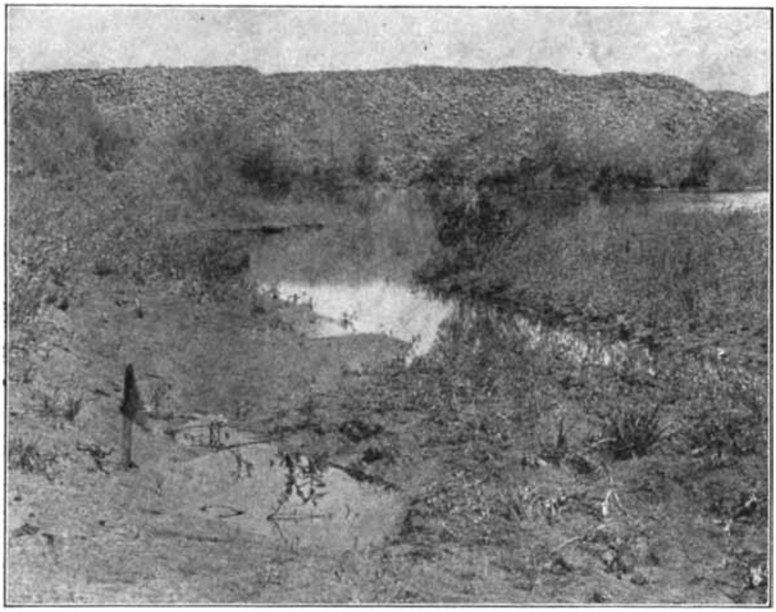


Fig. 98. — Receding streams leave pools of standing water along the banks, in which mosquitoes may breed plentifully.

two to inspection and follows this with an entire day of oiling and he may then need to use a good many gallons of oil in a few hours. A good-sized

Fig. 99. — Showing use of knapsack spray pump in mosquito control.

wad of cotton waste soaked in oil and placed in a pool of stagnant water will continue to give off oil for some time and is often very serviceable.

When to Apply Oil. — Oil should be applied whenever and wherever the wrigglers and tumblers are found, even though permanent correction is planned. This will prevent them from being washed out into some other situation where they would be liable to complete their transformation. The frequency with which oil must be applied depends on the rate of development of the wrigglers and the evaporation of the oil, — both conditions being dependent on the temperature. Therefore, more frequent applications are necessary during midsummer, when with the oil mentioned above, spraying should be repeated at least every twelve days, and under cooler conditions (averaging 50° to 60° F.) every three weeks. If it requires only ten days for some mosquitoes to pass through their entire transformation, one might think that applications of oil every twelve days would not be often enough, but it must be remembered that the oil kills all wrigglers and tumblers at the time of contact and the film remains on the water for about two days, sometimes longer, during which time any adult mosquito, intending to lay eggs, is killed on coming in contact with the oil. After the oil has evaporated quite largely, the breeding may begin again, but the next application of oil will catch the oncoming brood before the ten days necessary for complete development have expired.

Copper Sulphate. — Treating water with copper sulphate ($CuSO_4$) for the destruction of mosquito larvæ and pupæ has been proved ineffective, but it is nevertheless useful in cases where stagnant water is covered so badly with algæ as to retard the effect of insecticides. The writer has invariably had better results with oil applied to algæ-covered ponds after liberal treatment with copper sulphate, than when the latter was not applied. The same also held true for soapy laundry pools which have frequently been found to harbor abundant Anopheles larvæ. Copper sulphate is ordinarily used not in excess of one part per million of water.

Tobacco Decoctions. — The writer has thoroughly tested the efficiency of tobacco decoction, both in the laboratory and in the field, and has found it very effective, but the expense is prohibitive when it is used on a large scale. Sulphate of nicotine (Black leaf 40) made by the Kentucky Tobacco Products Company, was found to effectively destroy all wrigglers and tumblers when used in the ratio of 1 part to 750 parts of water. Greater dilution proved uncertain for the pupæ, but 1 to 1000 is still effective for larvæ. In field work this material was effectively used on smaller pools and also on a good-sized quarry-hole pond, but the cost proved too great. Ordinary " Black leaf " tobacco decoction cannot be used effectively in a greater dilution than 1 part to 20 of water. It must be remembered in all cases that a material in weaker strengths would be just as useful and less expensive provided it killed the insect, even after a day or two, and this factor was borne in mind during the progress of experimentation.

Smith found that "Nicofume" destroys all small wrigglers at the rate of 1 part in 2500 parts of water, and all wrigglers and eventually all tumblers at the rate of 1 part to 1500 parts of water. Rapid destruction was accomplished by using 1 part of "Nicofume" to 750 parts of water.

Other Larvæcides.—Many chemicals have been used experimentally against mosquito larvæ with more or less success, but in most cases either the cost or danger to life is forbidding, leaving oil still the simplest and cheapest remedy. Among the more effective remedies may be mentioned "Chloronaptholeum" used as a spray especially in cesspools and other unsanitary situations; Phinotas oil acts quickly as a poison even at very low concentrations, but should not be used where there is danger of poisoning. The simple addition of lime or chloride of lime to damp places with just enough water present to breed mosquitoes proves quite advantageous.

The writer's enthusiasm to carry on extensive experimentation with larvæcides, except as already noted, has never been fully worked up, owing to the fact that such materials are too often taken as an excuse for the more satisfactory permanent methods. The general public desires above all things a kind of magic remedy to be applied once with little trouble and permanent relief, whether the appearance of things has been improved or damaged, it matters not.

The use of larvæcides has, however, a very important place in the crusade against the mosquito, and until communities, whether large or small, learn to appreciate the advantage attained by proper drainage facilities and careful attention to prevent water from becoming stagnant, both early and late in the year, these materials must be used.

At the beginning of a campaign, when larvæ and especially pupæ are already present, a good larvæcide must be applied until proper drainage is secured.

"**Larvicide,**" generally used in the Panama Canal Zone, is prepared from crude carbolic acid. Its manufacture and method of application are fully described in an article by G. T. Darling in the *American Journal of Public Health* for February, 1912. From this the following is quoted:

"One hundred and fifty gallons of crude carbolic acid are heated in an iron tank having a steam coil with steam at 50 pounds pressure. Two hundred pounds of finely crushed and sifted common rosin are dissolved in the heated acid, and then 30 pounds of caustic soda dissolved in six gallons of water are added. There is a mechanical stirring rod attached to the tank. The product is ready in a few minutes, yielding about 3½ barrels. As a mosquito larvicide it is used by spraying an aqueous emulsion (one part of larvicide to five of water) over the surface and along the margin of pools and ponds or other mosquito-breeding places so that the resulting dilution of the larvicide has a thin, milky opalescence representing approximately a dilution of 1 to 5000." Water thus treated is poisonous to animals.

Permanent Corrections. — If a useless pond of water can be drained readily or filled, and this is very often the case, it is a foolish waste of

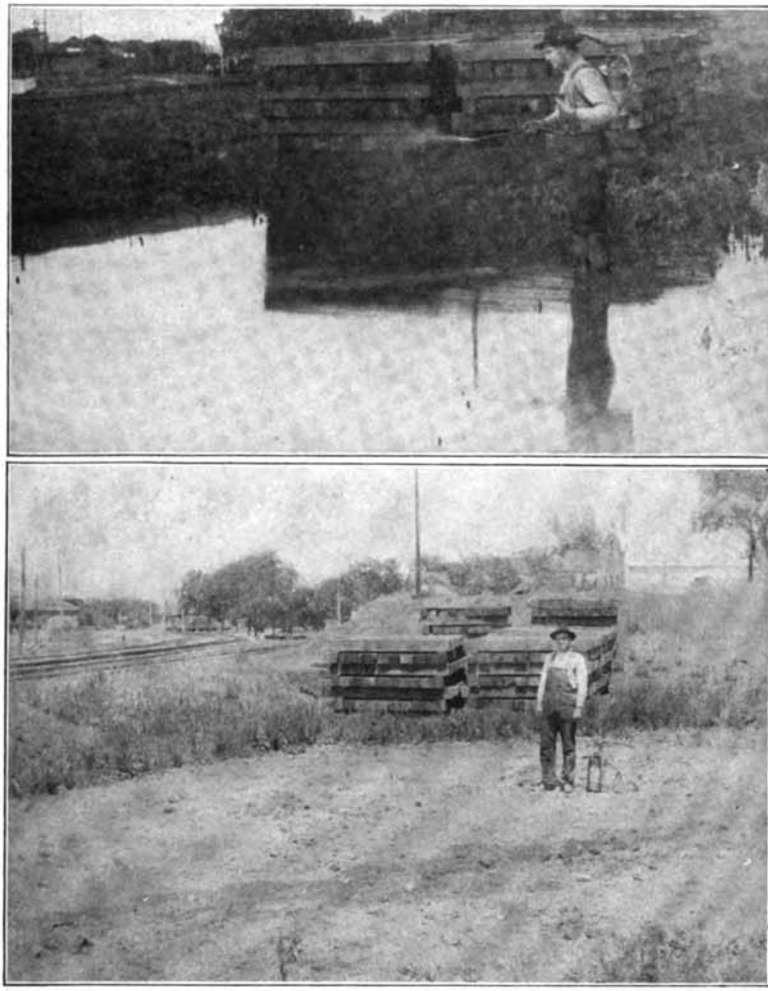


FIG. 100. — Upper figure shows a big pond adjacent to the railroad and caused by obstructing the natural drainage. A source of many mosquitoes every year. Oiling, while serving the purpose, requires repeated expenditure of time, labor and money. The lower figure shows the same spot after it had been permanently corrected by the railroad company.

time, energy and money to repeatedly oil it. Marshy land, otherwise useless for agricultural purposes, can in many instances be made tillable and at the same time free from mosquitoes by digging ditches of necessary depth together with proper lateral branches. Thus many acres have been reclaimed, made productive and at the same time inhabit-able. The dry summers prevailing in some sections, notably California, favor permanent corrective work, because pools of standing water drained off at the termination of the rains in spring remain dry for the rest of the summer. The wisdom of permanent corrective measures is recognized by all larger business interests as witnessed by their response to requests for aid in mosquito control (Fig. 100).

Irrigation. — It is quite commonly asserted that malaria makes its appearance together with irrigation. That is apparently true, but it

Fig. 101. — Breaks in the irrigation ditch are responsible for considerable inundation, producing favorable breeding places for mosquitoes, especially Anopheles. The rapidly running water in the ditch is unfavorable for mosquitoes.

need not be so if proper attention were paid to the best methods of irrigation. Certainly southern California is necessarily the scene of much irrigation, yet malaria is quite scarce, therefore irrigation as such cannot be a factor. The matter simply resolves itself to relative abundance of water; *i.e.* where this is abundant, as in northern California, it is used unsparingly and without regard for "leaky" ditches (Fig. 101) and great waste, resulting in ideal swamp areas for the propagation of the Anopheles mosquito.

With proper attention to irrigation methods, particularly drainage (Fig. 102), and the use of concrete, tile or metal waterways to prevent useless lateral seepage there need be absolutely no malaria associated therewith. Water should not be permitted to stand in pools for long periods, — usually twenty-four hours is sufficient. Water which has been standing ten days or over is dangerous, because it only requires ten days at the shortest in midsummer for the commoner species of mosquitoes to develop from the egg to the adult. Water that runs freely in the ditches is not favorable to the propagation of these insects.

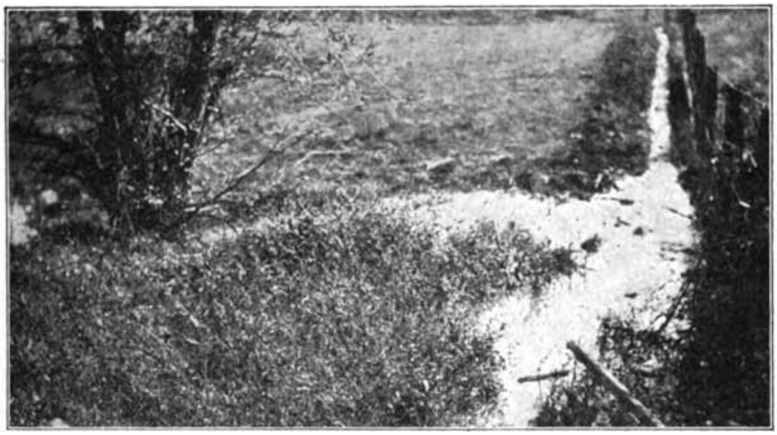


FIG. 102. — Drainage water resulting from irrigation, a source of myriads of mosquitoes. The small ditch in the background will remove the difficulty.

The poorly kept ditch is a bad investment in every way, an eyesore and a menace to health.

River Towns and Malaria. — As long as a river is high there will be little or no opportunity for mosquitoes to breed along its banks, but later in the summer, during June and July, many pools are left behind by the receding water (Fig. 98). The stagnant water becomes green with algæ and soon Anopheles are breeding in abundance. The same condition also commonly prevails along smaller streams. Many mosquito wrigglers may often be found developing in pools covered with green scum, and along the edges of the stream or creek where the current is very sluggish. In both cases the situation is controllable, as has been demonstrated. The pools along the banks of the receding river can be drained off, in nearly all cases, or can be thoroughly oiled. Thus a river town need not necessarily be a malarial town. And furthermore, the banks of a river or creek can be kept clean at a comparatively small cost and this need only be done for a distance of about 300 yards on either side of the community; in most cases a hundred yards less will serve very well because the Anopheles mosquitoes are not strong fliers, being bred as a rule very near the place where they are found.

Salt Marsh Mosquitoes. — Although the Anopheles does not breed in salt or brackish water to any great extent, some of the most formidable "biters" do, and, moreover, these latter may be carried by the winds for several miles from their breeding grounds and make life miserable for people living in communities unfortunate enough to be in the path of the invading horde. This can be corrected, however, for it is found that not all portions of a marsh are a menace. For example, the writer examined several miles of marsh in a given locality to locate the source of the pest and discovered that the breeding ground was restricted to a

FIG. 103. — Mosquito control work on a large scale. Permanent corrective work, — draining a large pond in the background. Salt marsh work in California.

comparatively protected area comprising only a few acres. For control it was recommended that ditches three to four feet deep be dug from the open water to the dry land, connecting these main ditches with short laterals, in order that the tide waters might sweep clear in and also to permit the extremely voracious little killifishes (Fundulus) to find their way unobstructed into every nook and cranny of the marsh.

The most extensive and elaborate salt marsh improvement work has been done in New Jersey under the direction of Smith,[1] the permanent results of which have more than repaid the amount appropriated for the purpose. Land which was previously useless became available for agricultural purposes and for summer homes, the increase in real estate valuation being an important factor (Fig. 103).

Summer Resorts. — An ideal summer resort is one in which mosquitoes do not take a prominent part. The Anopheles may not have

[1] Smith, J. B., 1904. Report of the New Jersey State Agricultural Experiment Station upon the Mosquitoes occurring within the state, their habits, life history, etc.

to be contended with, but the Culicine species are found more or less abundantly everywhere unless measures are taken to control them, and some of our summer resorts are far from ideal in this respect.

Imagine the joy and comfort of a mosquitoless summer resort on a fine summer evening under otherwise favorable circumstances, when it is possible to sit on the veranda without having to fight mosquitoes all the time! The ease with which these pests can be controlled and the advertisement that a mosquito-free resort deservedly secures should set managers working in this direction.

Screening. — Far too little attention has been paid to the proper screening of sleeping apartments. The time will come when screens will no longer be needed against intruding mosquitoes and flies, — indeed that day has already dawned for a few (a very few) thoroughly enlightened communities, which have discovered that these noxious creatures can be readily controlled.

Against mosquitoes nothing larger than the best one-millimeter mesh (No. 18) screen should be used. Mosquitoes are persistent and will work their way through a large mesh. Furthermore, in malaria-ridden districts it is time well spent to hunt down and destroy all mosquitoes that may have secured entrance despite the screens. It is also wise to carefully screen in all malaria cases at night so that Anopheles mosquitoes cannot become infected through the blood of such patients.

Campers, prospectors, soldiers, and others required to sleep out of doors should use special folding frames covered with mosquito netting. These are light and can be folded to convenient size for portage when not in use.

Cisterns, fire buckets, and other water receptacles need to be kept properly screened or securely covered.

Repellents. — Night laborers, watchmen, pickets, and others compelled to be on duty at night are, of course, exposed to the bites of mosquitoes and should exercise some precaution at least against these pests. Repellents of several kinds have been used with more or less success. The writer has found *oil of citronella* to be one of the most reliable deterrents when simply rubbed on the hands and face; a dozen drops or thereabouts being placed in the hollow of the hand and thus applied.

To this oil may be added various other ingredients; for example, Howard has found the following mixture most effective, viz.: 1 ounce of citronella, 1 ounce spirits of camphor, and one half ounce oil of cedar. Howard found this very satisfactory against *Culex pipiens* by applying a few drops on a bath towel hung on the head of the bed. He, however, adds that it is not effective against the yellow fever mosquito, which begins biting at daybreak when the oil has lost most of its strength.

Other deterrents used and recommended by various authors are: a mixture of castor oil, alcohol, and oil of lavender, equal parts; or a few drops of peppermint or pennyroyal, oil of tar, oil of cassia, or simply pure kerosene.

Repellent Plants. — Much has been written about deterrent trees and plants, but few, if any, have stood the test of accurate observation.

The writer's own experience together with that of other observers, does not credit the castor-oil plant nor the Eucalyptus tree with important deterrent properties; the same seems to hold true of the chinaberry tree and the pennyroyal plant.

Fumigants. — Knowing that mosquitoes often hibernate in great swarms in basements of buildings, cellars, and other favorable situations, it becomes necessary to destroy these in order to prevent them from propagating in the spring of the year. A number of very satisfactory fumigating agents may be mentioned, such as pyrethrum powder, sulphur dioxid (see p. 75), fumes of cresyl, pyrofume (a turpentine by-product), etc. J. B. Smith recommends Jimson weed fumes very highly. He recommends using powdered Jimson weed (*Datura stramonium*) at the rate of eight ounces per 1000 cubic feet of space, mixing it with one-third its weight of saltpeter to facilitate combustion. The mixture is to be spread on a tin pan or stone and ignited at several points. The fumes are not dangerous to human life.

Mosquito Bites. — Mosquito bites, while perhaps never serious in themselves, may lead to blood poisoning through scratching with the finger nails in the attempt to relieve the irritation, often intense. To relieve this irritation any one of the following may be applied, viz.: ammonia, glycerine, alcohol or iodin. According to Howard the most satisfactory remedy known to him is the application of moist toilet soap. He also mentions touching the puncture with a lump of indigo as affording instant relief, or touching the parts with naphthaline moth balls.

Natural Enemies. — One often hears others say that there is a natural "balance" in nature which should not be disturbed, and this argument is frequently advanced against the efforts of those engaged in mosquito control. It may be balm to such individuals to know that mosquitoes have also their natural enemies, if man can indeed be considered an unnatural enemy.

Among the less efficient enemies, owing to small numbers, are the dragon flies (Odonata), commonly called "mosquito hawks," "snake doctors," and "devil's darning needles." These insects may be seen in the evening darting hither and thither capturing mosquitoes and midges on the wing. Where bats are plentiful, these animals are highly spoken of as effective enemies of mosquitoes.

More effective enemies are found among the surface-feeding fishes, which are practically all of small size. Unfortunately, where mosquito larvæ are found there are also abundant other aquatic insects, so that the stock of fish must be correspondingly large in order to hold in check the insects aimed at. In such places where it is undesirable to apply oil and the water is not too shallow throughout its entire extent, fishes may play an important rôle; indeed the same thing may hold true in bodies of water where it is quite possible to apply oil. It can readily be seen that to transplant fish into anything but permanent bodies of water would be very poor policy. Ornamental ponds, reservoirs, springs, cisterns, tanks, and the like are among the instances in which surface-feeding minnows may be found useful.

The common goldfish (*Carassius auratus*) is at the same time one of the most ornamental as well as efficient fishes in this respect. The following quotation from Howard[1] after Underwood, referring to an ornamental aquatic garden near Boston, in which mosquitoes were kept in check by goldfish is apropos: "I took from the pond a small goldfish about three inches long and placed it in an aquarium where it could if it would, feed upon mosquito larvæ and still be under careful observation. . . . In the first day, owing perhaps to being rather easily disturbed in its new quarters, this goldfish ate eleven larvæ only in three hours, but the next day twenty-three were devoured in one hour; and as the fish became more at home the 'wigglers' disappeared in short order whenever they were dropped into the water. On one occasion twenty were eaten in one minute, and forty-eight within five minutes. This experiment was frequently repeated and to see if this partiality for insect food was characteristic of those goldfish only which were indigenous to this locality experimented with, some said to have been reared in carp ponds near Baltimore, Maryland, were secured. The result was the same. . . ." Similar results have been attained in a number of places both on the Atlantic and Pacific coasts.

One of the most valuable articles touching the control of mosquitoes by fish is that of Seal[2] for the *Scientific American*, in which he makes the following statements: "The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way or that may attract its attention. The one great objection is that they grow too large, and the larger will eat the smaller of them." The same observer concludes that "a combination of the goldfish, roach, and top minnows would probably prove to be more generally effective in preventing mosquito breeding than any other." The top minnows mentioned are *Gambusia affinis* and *Heterandria formosa*. In those bodies of water kept free from mosquito larvæ in California, McGregor, working for the writer, has observed that the following three species are primarily concerned, viz.: the Sacramento chub, *Leuciocus crassicandra*, the Sacramento pike, *Ptychocheilus grandis;* and the shiner, *Lavinia exilicauda*. The Barbadoes "millions" (*Cyprinodon dispar*) has been found useful as a mosquito destroyer in that country and elsewhere. In salt marshes the tiny killifishes (Fundulus) should be given every opportunity to reach all parts of the marsh. Where found, they are, as a rule, very abundant and are efficient as destroyers of mosquito larvæ.

Organization. — In order to conduct an effective civic anti-malaria mosquito crusade, there must be some responsible organization back of it. This may be a new body or an organization already in existence. It

[1] Howard, L. O., 1910 (*loc. cit.*).
[2] Seal, William P., 1908. Scien. Amer. Suppl., Vol. 65, No. 1691, pp. 351–352.

is absolutely essential that a committee at least be responsible as a medium between the citizens and the persons doing the actual control work.

In the several anti-mosquito crusades under the writer's direction the financial responsibility was undertaken in one case by a new organization under the name of " The . . . Anti-Mosquito League," with a president, vice president and secretary treasurer; in another case it was a committee of representative citizens with a chairman, a secretary and a treasurer; the committee was known as " The . . . Anti-Malaria-Mosquito Committee "; and in still another crusade the responsibility was undertaken by the " Mosquito Committee " of the Woman's Club. In no case could it be said that the mosquitoes were worse than in neighboring towns which might have led to such action, but the initiative could be traced to the progressive spirit of one or more citizens.

The financial responsibility having been undertaken by the respective organization, and a previous estimate of cost having been provided by some one familiar with such work, the next step in the campaign is to secure the services of a trained field agent or sanitary inspector who is to do the actual control work assisted by day laborers.

The *Inspector* or *Field Agent* must be an individual not only qualified technically but must have the ability and patience to inform those with whom he comes in contact as to the reason for his action if the work is to be of lasting benefit. This does not imply, of course, that words should be lost on persons who purposely interfere on the ground of ignorance, — he must therefore also be firm. Since sanitary inspectors in many communities are grossly incompetent, and are merely so-called inspectors, whose duty it is to occasionally peer into a toilet or tack up a contagious disease placard, the office does not imply the dignity that it ought, therefore the term *field agent*, was preferably employed in the writer's work in California.

With a responsible field agent in charge whose sole duty it is to protect the health of the community through the control of mosquitoes the success of a crusade should be assured.

The Cost. — The cost of an effective campaign is thought by some to be quite forbidding, but experience under conditions often apparently hopeless has shown that everything necessary can be done within reasonable limits. One good field agent can handle from eight to ten square miles of territory, and the salary of this individual represents the greatest outlay, unless much permanent corrective work is done, a matter which would increase the cost in the beginning, but would pay in the long run. The actual field work need not extend over much more than eight or nine months, from March to November inclusive at most. Capable men can usually be secured at a salary ranging from $75 to $125 per month, new men beginning with the first mentioned sum.

Considering the benefits derived in added comfort and improved health, double the cost above mentioned would be reasonable. It should be noted that in every crusade of this kind the *general* health conditions are improved.

In order that a campaign may be successful and that the work may continue unhampered, it is essential that sufficient funds be in sight to begin with. Raising funds is a matter that must be settled by each community for the present until such legislation has been brought about that will insure county or state aid. Thus far the task of raising funds has ordinarily been given over to the civic organizations which have solved the problem in one way or another through committees. Several committees have raised their funds by popular subscription; one other progressive town has had several tag days with gratifying results.

Under California conditions, for example, the average minimum cost of protection, giving to each field agent an area of ten square miles to cover, which is possible with some assistance, is about $.75 per day per square mile. At this rate the cost of an average crusade covering an area of ten square miles is about $1600 for one season, covering a period of eight months. Estimating the cost of quinine and doctors' bills at $20 per family, with not more than one hundred families within the ten square miles area (a low estimate) plus 25 per cent reduction in earning capacity per family with an average income of $800, gives a total loss of $20 × 100 (= $2000) + $800 × 100 × 25 per cent (= $20,000) = $22,000. Ordinarily it is possible to reduce the total amount of malaria by at least 50 per cent in one season. At this rate there is a saving of $22,000 × 50 per cent − $1600 = $9400 (nine thousand four hundred dollars) in one season to this scattered rural community. Surely this is a good investment.

The following table (Table II) is intended to give an idea of items involved in the monthly expense account.

TABLE II

Tabular Account of Monthly Expenses (for Oroville)[1] from March to July Inclusive, 1911

	March and April	May	June	July
Oil	$15.10	$2.50	$16.90	$25.45
Rig hire	9.50	10.50	9.00	9.00
Printing and stationery	11.50	——	——	——
Postage	1.60	.50	——	.50
Labor[2]	——	——	2.00	——
Sulphur	——	——	.50	——
Field Agent	March 10.00 April 125.00	125.00	125.00	125.00
	$182.70	$138.50	$153.40	$159.95

[1] The greater part of this work was confined to an area of about four square miles, including the city of Oroville, California, and only about one fifth of the time was spent in inspecting the rural surroundings.

[2] Practically all labor, to the value of approximately $120, paid by city street department and several private companies.

The above estimate of $.75 a day per square mile of protection does not include much permanent corrective work, and would continue from year to year without lessening greatly, though the educational factor will play an important part after two or three years, when individuals in a community will do considerable work of their own accord.

The following estimate (Table III), based on a thirty square mile area and including all necessary permanent corrective work of ordinary nature, shows conclusively that a larger primary investment is the cheapest in the end and certainly far more satisfactory.

TABLE III

ESTIMATED COST OF MALARIA CONTROL COVERING A THIRTY SQUARE MILE TRACT AND INCLUDING ALL ORDINARY PERMANENT CORRECTIONS. BASED ON A TAXATION PLAN.

ITEMS	FIRST YEAR	SECOND YEAR	THIRD YEAR
Assessor	$1000	$500	$200
Director	2500	2000	400
Field Agents	3200 (3)	2400 (2)	1500 (1)
Surveys	2500	——	——
Maps	750	——	——
Stenographer	900	200	——
Equipment (Teams, etc.)	2000	——	——
Labor	3000	200	100
Materials	1500	——	——
Feed	700	250	120
Supplies	100	50	——
Office (postage, etc.)	100	100	100
Oil	350	200	100
Incidentals	200	100	100
	18800	6000	2620
Ten per cent contingencies	1880	600	262
	Square miles 30)20680	30)6600	30)2882
	Days 365)689	365)220	365)96
Approximate cost per square mile per day	$1.90	$.60	$.27

When to Begin Work and when to Close. — The best results are secured in a new district by eliminating as far as possible the last brood of mosquitoes in the autumn, *i.e.* oil or drain off all mosquito breeding pools in October and go over the territory once again in November. In this way the number of mosquitoes which hibernate over winter is reduced to a minimum. The spring work should begin in March, depending on the weather, — if warm, the work must begin earlier in the month, if cool, then later. This can only be ascertained by inspecting likely pools in order to determine whether mosquito larvæ are present and what size they have attained. Usually the last larvæ are found in October and the campaign may usually close safely with the end of this month. This applies to the Anopheles mosquito (the malaria bearers) and does not apply to the Culicine varieties, including salt marsh species.

The Educational Factor. — Giving the answer to the questions, "Why?" and "How?" is the part the educator must play in the science of sanitation. If once the people of a town or village catch the vision of better things, and are taught how to realize these things, the problem is largely solved.

To help answer these questions at least one lecture, well illustrated by means of charts, lantern slides, and other material, should be given at the beginning of each campaign. This we generally follow up with brief newspaper articles, for the press is one of the greatest educational factors in America. Show window displays, in which the properly labeled living insects are exhibited as they pass through their various stages of development. Also the action of the oil can be thus nicely illustrated. The interest that this sort of display arouses is immense and few merchants hesitate to allow at least a part of their windows to be so used.

A laboratory may or may not be established in which the more scientific phases of the subject are illustrated by means of the microscope and other apparatus. The writer has found such laboratories very valuable since it gives the field agent an added impetus and adds to his efficiency in the field. Here the more detailed habits of the individual insect can be observed.

One of the most important factors in our work is that accomplished through the school children. The school children are visited in the classroom and the story of the mosquito wriggler is told, — how the mosquito carries disease and how to prevent it. Demonstrations with the living wrigglers can easily be made. Interesting essays are then written by the children and the best may be published in the local paper, all of which stimulates interest and gives the children a grasp on practical subjects. The lessons (Fig. 104) learned at this time will be applied at once, and a generation of citizens is reared with some knowledge of practical hygiene.

The use of a mosquito pin or button has resulted in much good. On answering some simple question, or after putting oil on a pool of water, the child receives such a pin from the inspector as a reward of merit.

Legislation. — In any malaria crusade all the inhabitants of a given district are equally benefited; it is therefore unreasonable that the entire cost of a campaign should be borne by a few individuals, which has been the case in several localities where funds were contributed through popular subscription. Because of the equal benefits derived, some plan of assessment or state appropriation seems to be more reasonable; however, the latter (state appropriation) may be objectionable unless all parts of the state are concerned. It should be borne in mind after all that bad advertising for one part of the state means injury to every other part, and the fact that malaria is present in any state is bad advertising. Be it also known that no community can hide the fact that malaria is present within its bounds, however strenuously its presence is denied. To carry on an anti-malaria campaign and then to widely advertise the fact is the best sort of advertising. Note the change of heart suffered by real estate dealers and boosters in several of the more progressive towns in malaria-ridden districts.

FIG. 104. — School children taking lessons in practical hygiene. The little boy in the foreground is preaching the gospel of good health to hundreds of children in many parts of the land by this example.

In January, 1911, an act known as the Guill Bill was introduced in the California legislature, and was passed by both houses, but did not receive the governor's signature. Had this bill become a law, it would have been the first state enactment of its kind in the United States directed specifically towards the extermination of the Anopheles mosquito by local communities with the object of controlling malaria.

The bill provided that the Board of Supervisors in any county, on its own motion or upon receiving a petition from ten or more taxpayers in the proposed district, should pass a resolution declaring its intention to do all work necessary for the extermination of Anopheles mosquitoes, describing the boundaries of the district to be benefited and assessed for the benefits. The petition mentioned was required to give the boundaries of the proposed district, to show that a survey had been made of the district under the direction of the State Board of Health, and that such survey showed that there were one or more breeding places of Anopheles mosquitoes within the proposed district.

The resolution of intention to do the work was required to be published, and opportunity was given to any one who objected to the work to appear before the Board and state his reasons for objecting. If they were not valid, the Board was to proceed to order the work done, appointing three commissioners to assess benefits and damages and have general supervision of the work. These commissioners were to have made a thorough sanitary survey of the district, make and map a careful description of the work required, and report the same to the Board of Supervisors. All objections to this report or any portion of it were then to be filed in writing with the county clerk, and at the next regular meeting of the Board these objections were to be heard and sustained or rejected or modified according to the judgment of the Board.

Certified copies of the report, assessment roll, and map were then to be filed with the tax collector, the taxes were then to be payable, and work to proceed as funds became available.

The state of New Jersey enacted effective legislation against salt marsh mosquitoes in 1906; the act reads: "An act to provide for locating and abolishing mosquito-breeding salt marsh areas within the state, assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect" and "for the purpose of carrying into effect the provisions of this act, the said Director of the State Agricultural Experiment Station shall have power to spend such amount as may be appropriated by the legislature, provided that the aggregate sum appropriated for the purpose of this act shall not exceed three hundred and fifty thousand dollars."

The first sound county legislation in the state of California has been enacted by the county of Tehama and reads as follows:

"ORDINANCE No. 46

"An ordinance to exterminate the mosquito larva.

"The Board of Supervisors of the County of Tehama, State of California, do ordain as follows:

"*Section* 1. No person or persons, firm or corporation shall discharge, pour, empty out, or otherwise place upon the surface of the ground in any lot, yard, street, road, alley or premises within the limits of the County of Tehama, State of California any water from any source which remains in a stagnant condition within two thousand (2000) feet of any occupied dwelling house, or maintain water in stagnant condition in any barrel, can, tub or open receptacle of any character whatsoever, within two thousand (2000) feet of any occupied dwelling house. *The presence of the mosquito larva in said water shall be conclusive evidence that said water is stagnant*, and upon the finding of said mosquito larva the occupant, or if the premises are unoccupied, the owner, shall be liable to arrest, fine and imprisonment as hereinafter provided, and if the said stagnant water, which is hereby deemed a nuisance, be not drained away or treated in a manner satisfactory to the Health Officer of Tehama County or his authorized representative, and within a reasonable period of time as determined by the Health Officer or his authorized representative, the said nuisance shall be abated by the Health Officer. The cost thereof shall be paid from the General Fund of the Treasury of Tehama County upon sworn warrant of the Health Officer, and the cost of said abatement shall be a lien upon the property upon which the said nuisance was created and abated, and shall be collected by law as taxes are collected.

"*Section* 2. Wells, cisterns, cesspools and privy vaults shall be so screened or covered as to prevent access to the contents thereof by mosquitoes, and such screens or covering shall be maintained in good condition and to the satisfaction of the Health Officer of Tehama County.

"*Section* 3. All violations of this ordinance shall be a misdemeanor, punishable by a fine of not less than five ($5.00) dollars nor more than fifty ($50.00) dollars, or by imprisonment in the County Jail for not less than five (5) days or more than fifty (50) days, or by both such fine and imprisonment."

Malaria Reduction as the Result of Anti-mosquito Measures is nicely shown by the following table (Table IV) after Cassa:[1]

TABLE IV

SHOWING DEATHS FROM MALARIA IN HAVANA FROM 1872 TO 1911 INCLUSIVE

The enormous reduction in deaths will be seen to begin with the inauguration of anti-mosquito measures in 1901.

Years	Total Deaths	Death Rate	Years	Total Deaths	Death Rate
1871	262	1.33	1892	286	1.33
1872	316	1.60	1893	246	1.12
1873	329	1.61	1894	201	0.90
1874	288	1.45	1895	206	0.90
1875	284	1.43	1896	450	1.95
1876	334	1.68	1897	811	3.48
1877	422	2.12	1898	1907	8.00
1878	453	2.28	1899	909	3.76
1879	343	1.72	1900	325	1.30
1880	384	1.93	1901	151	0.55
1881	251	1.26	1902	77	0.29
1882	223	1.12	1903	51	0.19
1883	183	0.91	1904	44	0.16
1884	196	0.98	1905	32	0.11
1885	101	0.50	1906	26	0.08
1886	135	0.67	1907	23	0.08
1887	269	1.34	1908	19	0.06
1888	208	0.99	1909	6	0.01
1889	228	1.11	1910	15	0.05
1890	256	1.23	1911	12	0.03
1891	292	1.37			

Figures 105 and 106 show graphically the results of anti-mosquito work at Ismailia and at Panama.

[1] Cassa, Jorge Le Roy Y., 1913. Sanitary Improvement in Cuba as demonstrated by statistical data. Amer. Journ. of Public Health, No. 3, Vol. III.

Results Obtained in Combating Yellow Fever Mosquitoes. — The table on next page, taken from Doane,[1] shows the death rate in Havana

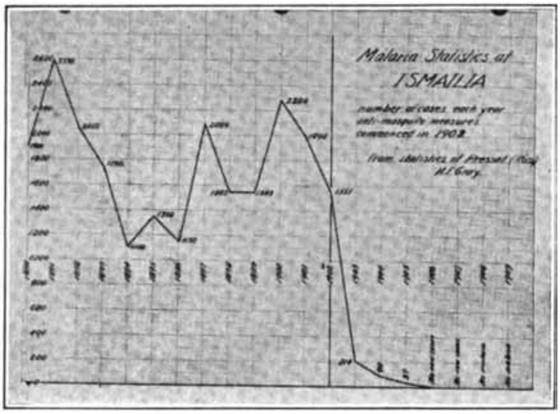


FIG. 105. — Curve showing reduction of malaria at Ismailia (Suez Canal) with the application of anti-mosquito measures in 1902.

due to yellow fever from the years 1893 to 1902 inclusive; the work of the Yellow Fever Commission based on mosquito control having been put

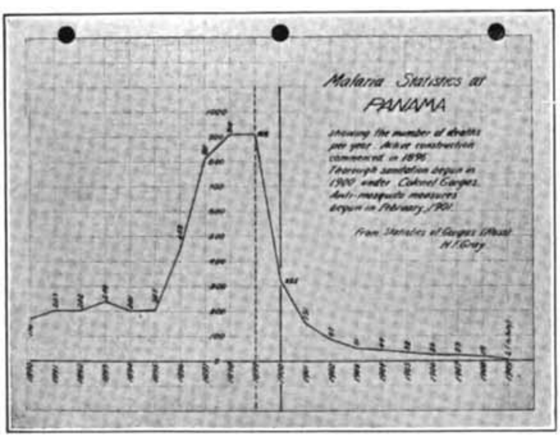


FIG. 106. — Curve showing reduction of malaria at Panama (Panama Canal Zone) with the application of anti-mosquito measures in 1901.

into effect in 1901 and 1902. Surely this table is eloquent in its praise of this splendid work.

[1] Doane, R. W., 1910. Insects and Disease. Henry Holt & Co., New York. pp. xiv + 227.

TABLE V

DEATHS IN HAVANA FROM YELLOW FEVER DURING YEARS 1893 TO 1902 INCLUSIVE

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
January . .	15	7	15	10	69	7	1	8	7	0
February .	6	4	4	7	24	1	0	9	5	0
March . .	4	2	2	3	30	2	1	4	1	0
April . . .	8	4	6	14	71	1	2	0	0	0
May . . .	23	16	10	27	88	4	0	2	0	0
June . . .	69	31	16	46	174	3	1	8	0	0
July . . .	118	77	88	116	168	16	2	30	1	0
August . .	100	73	120	262	102	16	13	49	2	0
September .	68	76	135	166	56	34	18	52	2	0
October . .	46	40	102	240	42	26	25	74	0	0
November .	28	23	35	244	26	13	18	54	0	0
December .	11	29	20	147	8	13	22	20	0	0

CHAPTER XII

BUFFALO GNATS AND HORSEFLIES

A. Buffalo Gnats

Order Diptera, Suborder Nematocera, Family Simuliidæ

Characteristics. — To the family Simuliidæ belong the tiny blood-sucking flies commonly called buffalo gnats, black flies, sand flies and turkey gnats. They are small dipterous insects ranging from 1 to 4 mm. in length, with a curiously humped thorax (Fig. 107) and blade-like piercing mouth parts. The antennæ are short cylindrical structures consisting of eleven segments. The wings are relatively broad and iridescent, and the venation is characterized by the strong development of the costal veins, the remaining ones being very weakly developed or absent. The Simuliidæ are world-wide in their distribution.

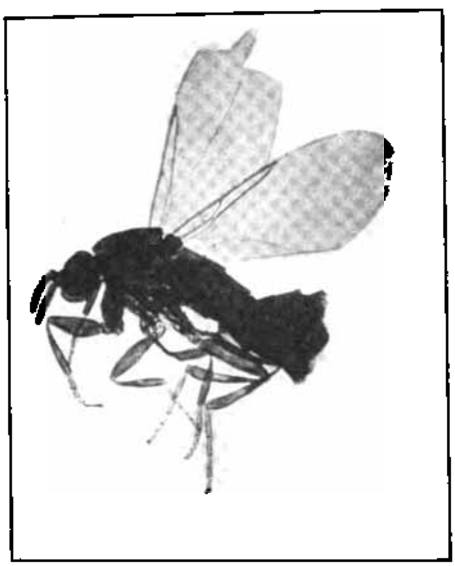


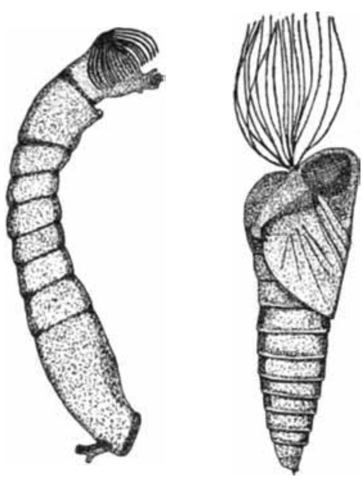
Fig. 107. — A buffalo gnat, *Simulium sp.* × 18.

Larvæ. — The brown to whitish larvæ are cylindrical, twelve-segmented, slightly thinner in the mid region, and when fully grown are from 10 to 15 mm. in length (Fig. 108*a*). The posterior end of the body is provided with a toothed disk-like sucker, composed of two modified parapodia. The anterior proleg is also modified into a prehensile toothed disk. By means of this organ, the larva moves from place to place with a looping motion. Through the agency of a secretion from the salivary glands, the larvæ are able to spin a silken thread to which they attach themselves, hanging from the end of the thread or moving along its length, the thread being attached to rocks or other débris.

Although the larvæ are provided with a well-developed tracheal system, there are no open spiracles, and respiration is carried on by means of gills, recognized as branched retractile structures located dorsally on the last abdominal segment. The fan-shaped filamentous structures located on the head are for the purpose of creating a current by means of which food is drawn to the mouth.

Pupæ. — The pupæ are quiescent and are loosely encased in silken cocoons or pockets. They are provided anteriorly with a number of long tracheal filaments (Fig. 108*b*), which are also of importance in classification.

Breeding Habits and Life History. — The adult buffalo gnats often occur in great swarms during the late spring and early summer in the neighborhood of marshes and forest streams. Occasionally swarms of these insects are seen far removed from moisture, but the reason for this is usually traceable to prevailing winds. At this time of the year the tiny white or whitish eggs are deposited in great numbers on the exposed, preferably wet, surfaces of rocks, grass, moss, brush and other débris in shallow streams of rather swiftly running water by preference. Comstock says he has often watched the gnats hovering over the brink of a fall where there was a thin sheet of swiftly flowing water, and has seen them dart into the water and out again. At such times he has always found the surface of the rock more or less thickly coated with eggs, and has no doubt that an egg is fastened to the rock each time a fly darts into the water.



a b

FIG. 108. — (*a*) Larva and (*b*) pupa of Simulium; latter removed from cone-shaped cocoon. (Redrawn after Lugger from Washburn.)

The time required for hatching is from ten to thirty days, depending on temperature. The newly emerged larvæ attach themselves to submerged objects, such as stones, logs, etc., by means of silken threads. Movement from place to place is gained by shifting their anchorage. In some favorable location, such as the riffles on the downstream side of an old log partially damming a little stream, there may be thousands of these tiny spindled larvæ. The larvæ as well as the pupæ being provided with gill filaments remain submerged. Growth is slow, the larval period covering the time from early summer to the following early spring, when full larval growth is reached. The larval period of some species is said to require but four to five weeks. The food of the larvæ consists of small crustacea, protozoa and algæ.

The pupal period is quite short in some species, requiring not over five or six days, while still others evidently require nearly a month. It is also true that temperature influences this stage, *i.e.* cooler weather retards the emergence of adults.

The Bite. — There is perhaps no other insect of equal size that can inflict so painful a bite as can the buffalo gnat. The mouth parts are of the Dipteron type, consisting of six blade-like lancets.

Human beings as well as domesticated animals are viciously attacked. The eyes, ears, nostrils, wrists and all exposed parts of the body are subject to attack. The extreme pain and the resultant local swelling, and occasionally complications, indicate the introduction of an active venom.

Losses due to the bite of this fly are estimated variously by stockmen. Washburn [1] states that " in 1884, in Franklin's Parish, Louisiana, they killed 300 head of stock in a week. In 1874 the state of Tennessee alone lost as much as $500,000 worth of stock from the attack of these flies."

Relation to Disease. — Owing to the intermittent blood-sucking habits of the buffalo gnats, it has long been suspected that these insects might play a part in the transmission of disease, but as a matter of fact, little experimental evidence is at hand to verify this suspicion. Since *anthrax* is comparatively easily transmitted from animal to animal, inasmuch as *Bacillus anthracis* is both exceedingly virulent and long-lived, it may be supposed that this disease could be transmitted, if any, but even here experimental evidence is wanting.

Since the rather startling statement of Dr. Louis W. Sambon [2] in 1910, referring the transmission of pellagra to a buffalo gnat, the study of Simuliidæ with regard to disease transmission has taken new impetus.

Pellagra. — This disease, also known as Alpine scurvy, sun disease and Asturian leprosy, has a very wide geographical distribution in semi-tropical countries, especially southern Europe. In the southern United States the disease has been increasing an hundred fold during the past two years or more.

The disease is manifested by annually recurring attacks of nervous and cutaneous symptoms. The symptoms reappear each year in the spring, gradually disappearing during the winter. The nervous symptoms are mainly in the form of melancholia, while the cutaneous symptoms are in the form of eruptions influenced by sunlight.

Both sexes are alike susceptible as well as all ages, except rarely infants. That the disease is most widespread among field laborers and country folk living near streams of water, and that the symptoms recur with the spring months has led to an investigation of the insect carrier theory. Heretofore the maize theory of spread was most generally

[1] Washburn, F. L., 1905. Diptera of Minnesota. University of Minnesota Agr. Exp. Sta. Bull. No. 93.

[2] Sambon, L. W., 1910. Progress Report Investigation of Pellagra. Journ. of Tropical Medicine and Hygiene, Vol. XIII, No. 19.

accepted, *i.e.* the theory that the disease was contracted by eating infected corn (maize).

Dr. Louis W. Sambon (*loc. cit.*) of the London School of Tropical Medicine studied the pellagra situation in Italy and in 1910 published a note on his investigations, viz.: "So far I have been able to establish:

"(1) That pellagra is not due to the eating of maize, either sound or deteriorated, as hitherto almost universally believed.

"(2) That it has a striking, peculiar and well defined topographical distribution.

"(3) That its endemic foci or 'stations' have remained exactly the same in many places for at least a century.

"(4) That its stations are closely associated with streams of running water.

"(5) That a minute blood-sucking fly of the genus *Simulium* is in all probability the agent by which pellagra is conveyed."

Professor H. Garmen of the Kentucky Agricultural Experiment Station has carried on recent extensive studies with regard to pellagra, and his findings are reported in Bulletin 159 (1912) from which the following extracts are taken, viz.:

"Looking at the matter from the point of view of the entomologist and naturalist it seemed to me very evident when I had examined only a few cases of pellagra that some agent in the air had to do with its spread, and it may be of interest to recall the facts that most appealed to me. In the first place the eruption on the hands began apparently about the bases of the fingers and extended thence upward to the elbows, where it stopped abruptly. On the legs it seemed to begin at the feet, affecting the upper surface and extending to the knees, where it terminated in a well-marked line. On the head and neck it affected in all cases examined only the skin constantly exposed, and terminated at the hair and at the collar. Yet in some instances there is an extension of the affected skin down upon the chest, coinciding somewhat closely with the opening in the shirt front. One such case, which I did not have a chance to see, was reported to me as residing at Old Straight Creek, above Pineville. All of these conditions seemed consistent with Dr. Sambon's theory that an insect carries the virus of the disease from ill to well, attacking the exposed skin and injecting into it something, bacteria or protozoa, which gives rise to the disease.

"Furthermore the disease is contracted and afterward becomes active in early spring just the time when our gnats of the genus *Simulium* come from the water in greatest numbers as adults.

"Again it often affects children, who constantly go barefooted and barelegged in this region and are disposed to play and wade in the streams. Women, too, were affected more than men, about the arms and neck generally, but also in some cases on the feet and calves. Men go less frequently with limbs bare, and are much less often attacked. The skin trouble appears upon the trunk rather rarely, though cases are on record of parts generally kept covered by clothing becoming affected.

"With these facts in mind, it was with very great interest that I examined a case at Moss' Camp above Pineville which seemed to oppose the idea of insect agency in the disease. The case was that of a middle-aged woman whose arms showed in a marked manner the symmetrical development of the skin lesions, so often mentioned by writers on the ailment. It was interesting further because it was then (Sept. 1) in an active condition, whereas all the other cases examined showed the usual summer cessation of the disease and an improvement in general health. The affected regions on the two arms were surrounded by a deep red border, as if something had got access to the blood in the center of the area and was spreading outward into the healthy skin, much as one sees in plants a fungus pushing outward from a point of inoculation by a growth of its mycelium. The area on the two arms and forearms seemed to be of about equal extent. This affected region was such as might at some time have been exposed to the air when the patient was busy about her domestic affairs. A more interesting and puzzling feature of this case was the presence of two isolated round spots of diseased skin, one on the point of each shoulder. If there had been one, I should have thought a hole in a gown might at some time have exposed the part to infection, but the chances seem against the presence of two such holes exactly alike, one on each shoulder. I am giving this fact as an illustration of what some physicians claim to be an invariable feature of the ailment, no matter where the skin trouble appears, namely, a symmetry in the skin affection, which they regard as evidence that the seat of the disease is within and the skin lesions only incidental and dependent. The case appears to support this view, yet it may prove when we know more of the conditions attending the contraction of the disease that such cases are still explainable on the theory of insect agency." Pellagra has been carefully studied by the United States Public Health Service, and in the Public Health Reports of October 23, 1914, Goldberger states that Pellagra is neither infectious nor contagious, that it is essentially of dietary origin, dependent on some yet undetermined fault in diet, and that the disease does not develop in those who consume a mixed, well-balanced and varied diet.

Gnat Control. — Knowing the breeding habits of the buffalo gnat, it will be appreciated that its control is a difficult task. The writer has repeatedly recommended that streams in which these insects are breeding should be kept as free from débris as possible, including dipping branches of overhanging trees and submerged roots. It is possible to do this in the immediate vicinity of communities, but prevailing winds may after all bring swarms of gnats from a distance. At all events the removal of débris from streams lessens the opportunity for them to deposit their eggs. Old logs lying crosswise of a stream are a particular menace because shallow waterfalls are thus usually produced, hence affording ideal breeding places for the gnats.

To prevent annoyance to beasts of burden some form of spray or ointment may be applied. While many repellents are on the market, few are of any benefit and practically none affords absolute relief. Any mixture containing fish oil is of some benefit, but must be applied daily. (See also under Hornfly.) Smudges act as good repellents, especially burning pyrethrum powder or buhach. Oil of citronella applied to the skin and face effectually keeps the insects away as long as the parts remain moist with the oil.

Systematic. — The family Simulidæ comprises about seventy-five described species (Williston), all in the same genus, *i.e.* Simulium. Two other genera are recognized by Mallock, namely, Prosimulium and Parasimulium. The best-known and most widely distributed species in America is *Simulium pecuarum* Riley, the buffalo gnat. Riley's description is here given as abbreviated by Garmen:

L

"*Male.* Eyes meeting and with two sets of facets. Mouth parts soft. Head black. Antennæ black, with some red. Maxillary palpi black. Thorax black above. Abdomen black, with grayish white posterior margins to segments.

"*Female.* Eyes not meeting. Head gray slate, with short yellow hairs. Eyes black, with coppery or brassy reflections. Antennæ black with whitish pubescence. Thorax grayish slate and generally distinctly marked with two mediodorsal and two subdorsal longitudinal black bands. Under side of thorax, grayish slate. Abdomen with a broad gray longitudinal band from near the base of the second segment, where it is broadest.

Simulium venustum Say is the black fly, a widely distributed species extending from Canada to Texas and from Florida westward. Say's description is as follows:

"Black: thorax, two perlaceous spots before and a larger one behind; poisers black; capitulum bright yellow, dilated.

"Body black; wings whitish, with yellow and iridescent reflections.

"*Male*, eyes very large, separated only by a single line, dull reddish yellow, inferior half black; thorax velvet black, a bright oblique, perlaceous, dilated line each side before, and a large perlaceous spot or band behind; sides beneath varied with perlaceous; feet, tibia above, and first joint of the four posterior tarsi white; abdomen with an oblique perlaceous line at base, and two approximate, lateral, perlaceous ones near the tip.

"*Female*, eyes moderate, thorax plumbous-black, immaculate, scutellum black, abdomen whitish beneath."

Simulium meridionale Riley is the turkey gnat, which also enjoys wide distribution coinciding with the buffalo gnat. This species attacks chickens and turkeys, biting the combs and wattles, and is said to produce symptoms similar to cholera.

Riley's description is given by Garmen as follows:

"The male is from 1.5 to 2 mm. in length, the eyes meeting above, where the facets are coarser and of a brilliant coppery luster, those on the ventral side smaller and black. Thorax dense black with bluish luster, ventral side grayish. Legs reddish with black tarsi. Abdomen above black, posterior margin of segments edged with gray. Ventral sides of segments two and three light reddish gray, the rest blackish with gray posterior margins."

The female is described by the same writer as from "2.5 to 3 mm. long; the head slate-blue, with silvery pubescence; the thorax, with three longitudinal lines, the median narrow and widening at the apex, the outer curving in at the base and out at the apex; beneath slate-blue; abdomen with last five segments dark blue above; segments 2, 3 and 4 each with a black cross bar; segments 5, 6 and 7, with two submedian stripes, disappearing on 7; bluish white everywhere beneath; legs brownish black."

Simulium occidentale Townsend is perhaps only a variety of the turkey gnat and is found in New Mexico. It is described by Townsend as follows:

"This species is smaller than either *S. pecuarum* or *S. meridionale*. *S. occidentale* differs from *S. pecuarum* very markedly in the thoracic and abdominal markings. These markings are very much like those of *S. meridionale;* but the median thoracic line is always very faint, the abdomen is light fulvous, the lateral lines of segments 5, 6 and 7 are curved, and the abdominal markings are of a different color, besides other minor differences."

Simulium columbaczense Schoenbauer is the Columbacz midge of Europe, especially abundant in the Valley of the Danube.

B. Horseflies

Order Diptera, Suborder Brachycera, Family Tabanidæ

Introduction. — To the family Tabanidæ belong the biting flies commonly called horseflies, gadflies and deer flies. All the genera belonging to this family consist of large flies (10–25 mm.), the body is heavy and the head possesses very large eyes. In the female the eyes are widely separate (dichoptic), while in the males the eyes are contiguous (holoptic). The flight is very swift and direct. The antennæ (Fig. 28) are short (Brachycera) and porrect, consisting of three joints, the third joint being annulated; the arista is absent. The wing venation (Fig. 17) is simple and characteristic.

Larvæ. — The larvæ (Fig. 109*b*) are spindle-shaped, tapering at both ends; are eleven-segmented, each segment being clear cut and provided with a circlet of tiny spines which aid in locomotion. The terminal segment bears a pair of stigmal openings and is somewhat prolonged to form a breathing tube.

Pupæ. — The pupæ (Fig. 109*c*) are provided with a conspicuous circlet of spines at the apical end of each abdominal segment.

Breeding Habits and Life History. — The Tabanidæ are aquatic or semi-aquatic in breeding habits. The eggs to the number of two to three hundred are deposited in irregular masses (Figs. 109*a*–110) on marsh or swamp vegetation, for example the leaves of Sagittaria, or on the leaves and twigs of trees (*e.g.* willows) overhanging ponds or sluggish streams. In the Sierra Nevada mountains horseflies occur in great numbers at elevations of 8000 to 9000 feet, where they breed in the soggy ground produced by springs and water from the melting snow. Deer and other wild animals suffer terrible torment in the summer time in these localities from the bites of horseflies.

The eggs, covered with a protective secretion, are deposited in early and late summer. The larvæ hatch in from five to seven days, depending on the species, the larger forms requiring somewhat more time than the smaller ones. The larvæ on hatching fall to the surface of the water, penetrate the surface film and then drop to the bottom, or if there is no water, the larvæ burrow into soft mud. Moisture is certainly necessary for their development. Insect larvæ, crustaceans and other soft-bodied animals provide food for these voracious, carnivorous creatures; cannibalism is also practiced. The larvæ grow rapidly during

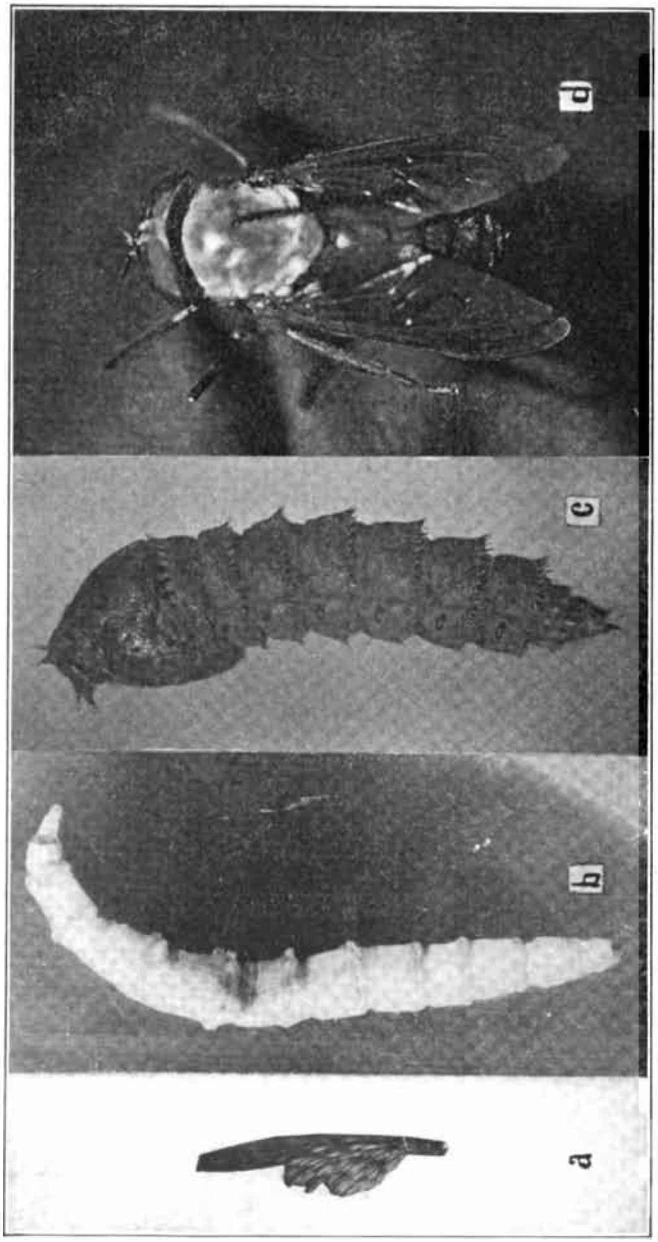


FIG. 109.—Showing life history of a typical horsefly (Tabanus). (a) egg mass; (b) larva; (c) pupa; (d) adult. ×2.3.

the rest of the summer and autumn, and very slowly, if at all, during the winter. They attain full growth in early spring, crawling out of the softer wet mud and into drier earth, where they pupate. The pupal period requires from two to three weeks. The emerging flies take refuge among the foliage of near-by trees and the females soon begin attacking warm blooded animals. The males do not suck blood, but feed on nectar and other plant juices. Unless swept up with an insect net in grass and other vegetation the males are seldom seen.

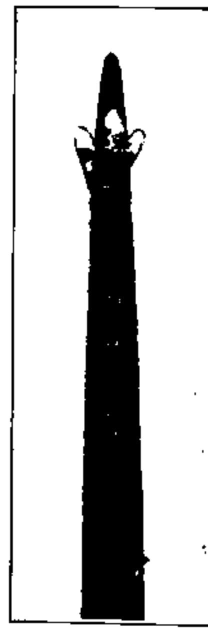


Fig. 110. — A horsefly (Chrysops) in the act of oviposition. Note also an egg mass farther down on the leaf. (Photo by Hine.) × 1.

Bites. — The horseflies have broad blade-like mouth parts (Fig. 28) by means of which a deep wound is cut, causing a considerable flow of blood. The bite is painful and owing to the intermittent habits of the flies there is great danger from infection.

In describing an outbreak of gadflies in Kentucky, Garmen has the following to say:[1] "Beef cattle had lost an average of 100 pounds as a result of the constant annoyance from them. . . . On cattle I counted from ten to nineteen. On mules and horses in harness they were a constant annoyance and even hogs were not exempt. Seven of the flies were counted on the exposed side of one of these animals lying in a puddle.

"The persecuted stock appeared to have given up fighting their enemies and allowed them to have their way. The switch of a cow's tail was observed to pass over the backs of clinging flies without causing them to move. . . . During the middle of the day animals suffered so much that they refrained from grazing at all, either standing close together about the barn or else lurking singly in thickets or standing in pools formed by small streams."

Relation to Anthrax. — The horseflies are decidedly intermittent in their biting habits, and inflict a definite lancet-like prick from which blood exudes so that the proboscis becomes soiled. The flies will bite sick animals as well as healthy ones, — hence the possibility for the transmission of an infectious blood disease seems to exist. It is regrettable that so little experimental evidence is at hand; however, anthrax is at once thought of, owing to the virulence and hardiness of the causative bacillus.[2]

[1] Garman, H., 1910. An outbreak of gadflies in Kentucky. Kentucky Agricultural Exp. Sta., Bull. No. 151.

[2] Mr. M. B. Mitzmain has verbally informed the writer (Feb. 17, 1914) that he has successfully transmitted anthrax from artificially infected guinea pigs to healthy guinea pigs through the agency of both *Tabanus striatus* and *Stomoxys calcitrans*. A preliminary account of these experiments is in the Journal of Tropical Medicine and Hygiene (London), Vol. XVII, No. 4.

Anthrax, also known as malignant pustule or carbuncle, wool sorter's disease, charbon (French), is caused by *Bacillus anthracis*. Nearly all species of domesticated animals and man are susceptible; the herbivora and rodents are most liable to infection. The mortality may be as high as 70 to 90 per cent.

After the introduction of the organism into the animal the incubation period is exceedingly short, *i.e.* from three to six days. The bacilli are seen in the blood stream in advanced cases as chains of rod-shaped bodies (Fig. 111).

Entrance to the body is gained mainly in one ot three ways, 1st, through lesions or pricks, *i.e. inoculation*, producing local anthrax or malignant pustule; 2d, by *inhalation* of the spores, producing pulmonary anthrax; and 3d, by *ingestion* with food, producing intestinal anthrax.

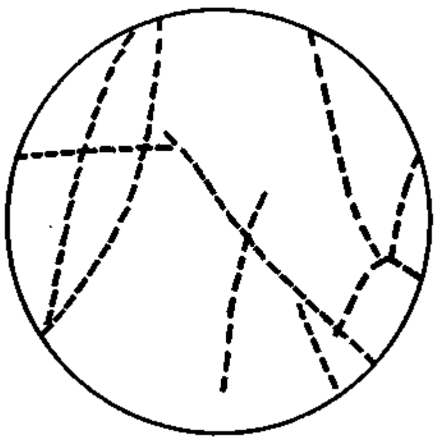


FIG. 111. — *Bacillus anthracis*, causative organism of anthrax. (Greatly enlarged.)

Manifestly horseflies could only relate directly to the first mode of infection (inoculation), but it is not altogether improbable that an epidemic of anthrax may thus be started and assisted in spreading. Nuttall cites Bollinger (1874), who captured horseflies on a cow dead from anthrax and saw the bacilli in preparations made from the stomachs and intestines of the insects. Two rabbits inoculated therewith died of anthrax. Of course, the insects would have to be crushed on the animal, and the wound produced by the bite thus infected in order to produce the disease.

However, many instances are recorded in which apparently the simple bite of the fly was all that was needed to produce malignant pustule in humans. Several reputable physicians have related instances to the writer in which this was said to have occurred, notably one case in a Western state in which a man was in the act of burying a cow dead of anthrax when he was bitten severely in the back of the neck by a horsefly and in a few days developed a malignant pustule. Nuttall also cites a number of similar instances.

Relation to Surra. — Surra is a highly fatal disease of horses and other susceptible animals, such as the carabao, which latter may evidently become chronic carriers. Guinea pigs and monkeys are also highly susceptible. The disease is endemic in the Philippine Islands, southern Asia, Korea and Madagascar. The causative organism is *Trypanosoma evansi* Steel which resembles the trypanosome of Nagana very closely, as do the symptoms, *i.e.* there is fever, œdema of the abdomen and genitalia, marked depression and emaciation. The trypanosomes are found in the blood and especially the lymph swellings from the beginning of the first symptoms. The incubation period is from eight to nine days.

Mitzmain [1] has been successful in transmitting the disease from animal to animal through the agency of a horsefly, *Tabanus striatus* Fabr. (Fig. 112).

In a series of experiments in which *Tabanus striatus* was used, he allowed the flies to first bite an infected guinea pig or horse for not more than one minute, usually forty-five seconds, and then transferred them to a healthy animal where they were allowed to complete the meal without interruption. An interruption of five seconds to three minutes was necessary to transfer the flies from animal to animal. The horses and mule employed in these experiments were kept in a screened stable for from six to eight months previous, and the monkeys, guinea pigs and rabbits in fly-screened cages for about ninety days. In all cases the animals were examined frequently (blood examinations made) and declared surra free at the time the experiments began.

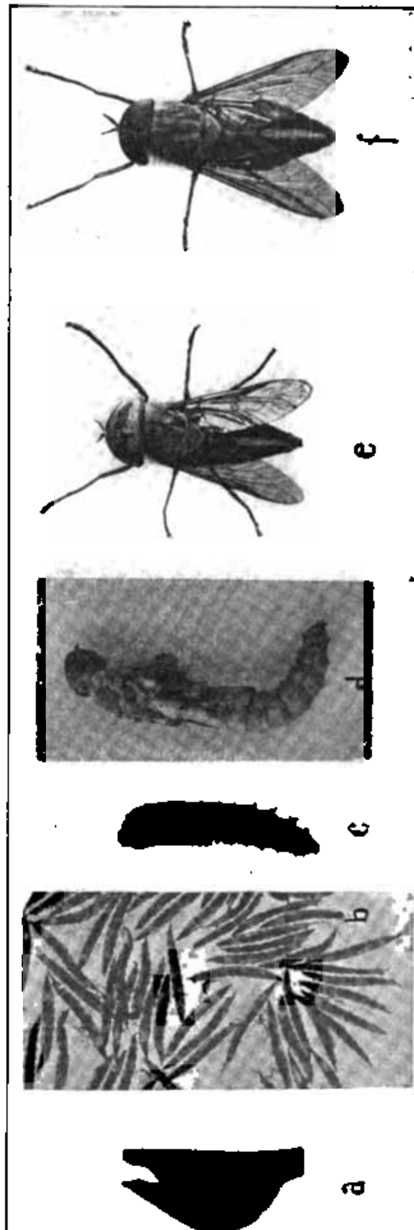


Fig. 112. — Life history of *Tabanus striatus*, a carrier of surra in the Philippine Islands. (*a*) egg mass; (*b*) a group of larvæ; (*c*) pupa; (*d*) imago emerging from pupa case; (*e*) adult male; (*f*) adult female. (Photo by Mitzmain.) ×2.

[1] Mitzmain, M. B., 1913. The mechanical transmission of Surra by *Tabanus striatus* Fabricius. Philippine Journ. of Sci., Vol. VIII, No. 3, Sec. B, pp. 223–229.

Flies bred from eggs were allowed to bite a guinea pig which had been inoculated with blood from a carabao which had been infected with surra for nearly a year previous to the experiment. Three flies were applied individually in tubes to the surra-infected guinea pig and allowed to feed from forty-five seconds to one minute and thirty seconds, after which they were transferred to a monkey and allowed to feed until satisfied, *i.e.* from five to twenty-one minutes. The first high temperature, 40.1° C., occurred on the eleventh day, accompanied by a few trypanosomes in the peripheral circulation, increasing in numbers until the death of the monkey on the twenty-fifth day.

Blood from the heart of this monkey was inoculated into a horse and two guinea pigs. The latter showed infection on the eighth and ninth days respectively, and the horse on the seventh day. Two flies were permitted to bite this horse, the insects being interrupted in their biting in from forty to forty-five seconds and then transferred to a healthy horse where the feeding was completed. This animal showed numerous trypanosomes in its circulation on the ninth day. Thus positive results were secured in both a monkey and a horse.

Blood from this newly infected horse was inoculated into a mule, two monkeys and two guinea pigs, all of which became infected in due season, both monkeys dying on the fourteenth and fifteenth days respectively.

A second series of experiments was carried on with captured flies, which were allowed to bite the above-mentioned surra horse and later a healthy horse, similar feeding methods being observed. This experiment also proved positive, as did blood inoculations to monkeys and guinea pigs.

In order to eliminate the possibility of hereditary transmission of trypanosomes in the flies a further experiment was conducted, in which seventy-four flies, hatched from eggs of a fly which had previous to egg deposition fed on a surra monkey, were allowed to bite a healthy monkey during a period of two weeks with negative results.

Mitzmain concludes that the " contaminated labellum of the fly does not appear to be a factor in the conveyance of infection. The maximum length of time that *Trypanosoma evansi* has been demonstrated microscopically in the gut of this species of fly after feeding on infected blood is thirty hours; the organisms were found in the fly's dejecta two and one half hours after biting the infected animal; and suspension of flies, when injected subcutaneously, were found infective for animals for a period of ten hours after the flies had fed on infected blood."

In a letter to the writer under date of Nov. 18, 1913, Mitzmain states that " infection is not transferred by *Tabanus striatus* later than twenty minutes after the infective meal. The longest time I have succeeded in inducing flies to transmit was fifteen minutes and all results from twenty minutes to forty-eight hours were entirely negative. This despite the fact that trypanosomes survive in the intestinal tract of *T. striatus* for a period of thirty hours." Mitzmain believes this horsefly to be the principal carrier of surra and that the stable fly, *Stomoxys calcitrans*, is ruled out, which is indeed indicated by the long and careful series of experiments conducted by that worker on both species of flies.

Control. — Inasmuch as the painful bite of the Tabanidæ, especially if these insects are abundant, makes the life of domesticated animals, notably horses, quite unbearable, it is desirable that some repellent substance or mechanical means be employed to prevent injury. Efficient repellents usually contain fish oil, which is disagreeable and in the presence of dust produces a very filthy coat; other materials in use are " dips " and these do not as a rule act for more than a few hours at most. Furthermore where whole herds of animals are to be treated, this method is impracticable. Horse nets afford considerable relief, and often avert dangerous " runaways."

Comparatively little of a preventive nature has been done, except for the notable work of Porchinski, reported by Howard.[1] Porchinski observed that Tabanids collect in great numbers in the neighborhood of humid spots and lower themselves to the surface of pools to drink, actually touching the water with their bodies. It occurred to him that a covering of kerosene on the water would endanger the lives of the insects as they came in contact with the surface. Hence a quantity of kerosene was applied to a given pool, with most gratifying results. By the third day of the experiment the " pool of death " was covered with " floating islands " of dead Tabanids. Porchinski recommends that a favorite pool be selected, and that the oil be poured on so that a thick uniform layer of oil is formed covering the entire pool. Such " pools of death " apparently attract the Tabanids from over a considerable adjacent area. The oil must of course be applied as early as possible during the season when the adult flies appear and begin to mate and deposit eggs.

Systematic. The following description of family characters and key to the North American Genera is according to Hine,[2] our highest authority on the Tabanids.

"The family Tabanidæ includes medium-sized to large insects commonly called horseflies, gadflies, deerflies, dogflies, earflies and various other names. Usually its members are readily recognized at sight by their form and general appearance.

"The three-jointed antennæ with the third joint annulated and without a style or arista, the rather large tegulæ, and the well-developed pulviliform empodia taken together serve to distinguish them from other flies in case of any doubt.

"None of the species are really small; the head is large, larger and hemispherical in the male, smaller and somewhat flattened in the female.

[1] Howard, L. O., 1899. A remedy for gadflies. Porchinski's recent discovery in Russia, with some American observations. U. S. Dept. of Agric., Div. of Entomology, Bull. 20, N. S.

[2] Hine, James S., 1903. Tabanidæ of Ohio. Ohio State Academy of Science, Special Papers, No. 5.

"The antennæ are porrect and composed of three segments of which the third is compound, having five or eight annulations. When there are eight, the basal one is only slightly longer than the others, but when there are five, the basal one is much longer than any of the others, often longer than all the others combined.

"The eyes are separated in the female and contiguous in the male. They have an area of enlarged facets above in the latter sex, and in life are marked with green and purple markings in both sexes. In dry specimens these markings are lost, but may be partially restored by moisture. Ocelli are present in some species and absent in others; and the occiput is flat or concave. The proboscis projects and in some species is much elongated; the maxillary palps are large and two segmented.

"The thorax and abdomen are clothed with more or less hair, but no spines or bristles. The wings are rather large and encompassed by the marginal vein, two submarginal and five posterior cells present, basal cells elongate, anal cell usually and sometimes some of the posterior cells closed. Tegulæ always prominent. Legs ample; pulvilli moderate; empodia developed pulviliform; middle tibia with spurs at the tip.

"Abdomen composed of seven visible segments, broad, never constricted."

KEY TO THE NORTH AMERICAN GENERA OF TABANIDÆ
(after Hine)

1. Hind tibiæ with spurs at the tip, sometimes small 2
   Hind tibia without spurs 6
2. Third segment of the antenna composed of eight annuli, the first of which is only a little longer than the following ones 3
   Third segment of the antenna composed of only five annuli, the first of which is much longer than any of the following ones; ocelli present 5
3. Front of female narrow; ocelli present or absent; fourth posterior cell at least open . . . . *Pangonia*
   Front of female broad with a large denuded callus; ocelli present . . . 4
4. Eyes in the female acutely angulated above; wing in both sexes with a dark picture . . . . *Goniops*
   Eyes in the female not acutely angulated above; wings hyaline in both sexes *Apatolestes*
5. Second segment of the antenna about half as long as the first; eyes in life with numerous small dots . . . . *Silvius*
   Second segment of the antenna as long or but little shorter than the first; wings with a dark picture . . . . *Chrysops*
6. Third segment of the antenna without, or with a rudimentary basal process 7
   Third segment of the antenna with a well developed basal process *Tabanus* [1]
7. Front of female as broad as long, the callus transverse . . . . *Hæmatopota*
   Front of the female narrow . . . . *Diachlorus*

A description according to Hine of a few of the commoner species is here included.

(1) *Tabanus atratus* Fabricius, the black horsefly (Fig. 113), is from "16–28 mm. in length. The male and female of this common species are easily associated as they differ only in sexual characteristics. The whole insect is uniformly black and the thorax and abdomen in well-preserved specimens are thinly covered with a whitish dust which is easily rubbed off when the specimens are not properly cared for.

[1] Including *Atylotus* and *Therioplectes*.

"It cannot be confused with any other species recorded, but the smaller specimens resemble *wiedemanni* very closely. The wider front, the longer

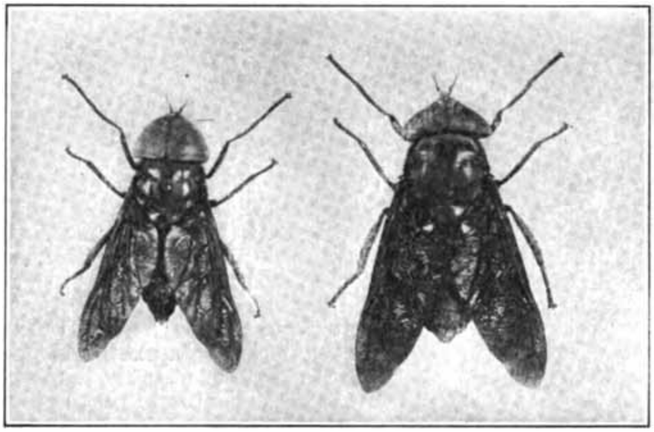


Fig. 113. — The black horsefly (*Tabanus atratus*); male at left, female at right. × 1.5. (Photo by Hine.)

basal process of the third antennal segment and the shape of the frontal callosity, which is square in *wiedemanni* and wider than high in *atratus*, are distinctive characters. Its much larger size and less shining color distinguish it from *lugubris*."

(2) *Tabanus stygius* Say is the black-and-white horsefly. "Length 20–22 mm. Third segment of the antennæ red at base, blackish at apex, first and second segments and palpi dark; legs black, often the tibia reddish at base; wings yellowish brown with posterior border approaching hyaline, a brown spot on the bifurcation of the third vein, also the transverse vein closing the discal cell margined with brownish; abdomen uniform black.

"Female: Thorax dorsally plainly whitish pollinose with more intense longitudinal lines.

"Male: Thorax dorsally uniform grayish brown in well-preserved specimens."

Fig. 114. — A black-and-white horsefly (*Tabanus punctifer*) common in California. × 2.

(3) *Tabanus punctifer* O. S. is also a black-and-white horsefly (Fig. 114) resembling *T. stygius*, except that it has the front tibiæ white on the basal third and the thorax uniformly white in both sexes.

(4) *Tabanus costalis* Wied., the green head, is one of the most-dreaded stock pests. "Length 12–14 mm. Palpi yellowish, antennæ brownish with the

annulate portion darker; thorax including the scutellum uniformly grayish yellow pollinose; legs largely black, base of front tibiæ and the middle and hind tibiæ except at apex yellowish; wings hyaline with the costal cells yellowish, veins yellowish; abdomen above alternately striped with black and grayish yellow.

"Female: Frontal callosity black, above with a very much narrowed prolongation, the part of which adjacent to the callosity is sometimes obliterated leaving the upper part as a separate spot.

"Male: This sex is much like the female and easily associated with it, but there is a tendency toward obliteration of the distinct markings of the abdomen, the black of the female is replaced by brownish and the stripes may blend so that the whole base of the abdomen is practically one color."

(5) *Tabanus lineola* Fabr., the lined horsefly (Fig. 115), is also an important stock pest. "Length 12–15 mm. Palpi white; antennæ reddish, annulate portion of third segment darker; thorax brown and gray striped, the latter color not prominent; wings hyaline; legs reddish, apex of the front tibia plainly, apexes of middle and hind tibiæ faintly, and all of the tarsi dark brown; abdomen above brown or black with three prominent, gray stripes.

FIG. 115. — The "lined" horsefly (*Tabanus lineola*). × 3.

The males and females of this species are easily associated. In the latter sex there is sometimes a confusion of colors; the dark is replaced by reddish but the gray mid-dorsal stripe is always prominent in all well-preserved specimens."

(6) *Tabanus sulcifrons* Macq. is known as the autumn horsefly. "Length 18–21 mm. Palpi brownish, antennæ nearly black with the third segment brownish at base; legs dark, bases of tibiæ darker; wings with a distinct brownish tinge, cross veins at the end of the discal cell and bifurcation of the third vein margined with brown.

"Female: front with parallel sides, frontal callosity shining brown, not quite as wide at the front, nearly square and with a linear prolongation above. Segments of the abdomen above with prominent gray, hind margins which expand into large gray triangles in the middle; usually a black mark on the anterior part of each of the second and third segments at the apex of the gray triangle.

"Male: The division between the large and small facets of the eye prominent; head slightly more convex than in the female but nearly of the same size, coloration of the whole body the same as in the female."

(7) *Tabanus striatus* Fabr. (Fig. 112) is said to be the most prevalent horsefly of the Philippine Islands, and is known to be an important carrier of Surra. The following description is after Mitzmain (*loc. cit.*).

"The male is very distinct from the female, being smaller and having a larger head and different color markings.

"The distinctly clavate palpi are shorter than in the female, only two thirds as long as the labium; they are dirty white and fringed with moderately long black hairs.

"The abdominal color markings take the form of a T of pale cadmium yellow in a field of burnt sienna, bordered with pale clay yellow. The area of the large facets of the eyes is colored Roman sepia surrounded by an elliptical band of ultra ash gray. The field of small facets has a mauve fringe bounding an area of iridescent mauve and Prussian green.

"Size: 14 to 15 millimeters.

"Wing expanse: 25 to 28 millimeters.

"Female: The front is narrow, converges slightly anteriorly; the color is golden, marked with a black callosity of irregular form.

"The head is considerably smaller than that of the male; eyes iridescent mauve and Prussian green.

"The palpi are prominently conical, as long as, or slightly longer than, the labium; the color is the same as in the male, mottled with short black hairs.

"The abdomen is alternately striped with Cologne earth and pale clay yellow. The median stripe is pale clay yellow. In both sexes the thorax is indistinctly striped with pale clay yellow and pale brown, and the wings are transparent except the costal and subcostal cells which are pale brown.

"Size: 15 to 17 millimeters.

"Wing expanse: 26.5 to 29 millimeters."

CHAPTER XIII

THE COMMON HOUSE FLY

Order Diptera, Family Muscidæ

LIFE HISTORY, HABITS AND RELATION TO DISEASE

Family Muscidæ. — The family Muscidæ, to which the house fly (*Musca domestica* Linn.) belongs, has the following characteristics: "Rather small to moderately large, never elongate, thinly hairy or bare flies. Antennal arista plumose to the tip, sometimes above only, and rarely bare, in which cases the absence of bristles on the abdomen, except at tip, together with the narrowed first posterior cell, characters distinctive of the group, will distinguish the flies belonging here from their allies. Eyes of the male approximated or contiguous; front of female broad. Eyes bare or hairy. Abdomen composed of four visible segments. Genitalia not prominent" (Williston[1]).

FIG. 116. — The common house fly (*Musca domestica* Linn.). × 4.

Characterization of the House Fly. — Hewitt's[2] description of the house fly after Schinir is undoubtedly the best for our purpose, viz. "Frons of male occupying a fourth part of the breadth of the head. Frontal stripe of female narrow in front, so broad behind that it entirely fills up the width of the frons. The dorsal region of the thorax dusty gray in color with four equally broad longitudinal stripes. Scutellum gray with black sides. The light regions of the abdomen yellowish, transparent, the darkest parts at least at the base of the ventral side yellow. The last segment and a dorsal line blackish brown. Seen from behind and against the light the whole abdomen shimmering yellow, and only on each side of the dorsal line on each segment a dull transverse band. The lower

[1] Williston, S. W., 1896. Manual of North American Diptera. James T. Hathaway, New Haven.

[2] Hewitt, C. Gordon, 1910. The House Fly. xiii + 195 pp. The University Press, Manchester, England.

part of the face silky yellow, shot with blackish brown. Median stripe velvety black. Antennæ brown. Palpi black. Legs blackish brown. Wings tinged with pale gray with yellowish base. The female has a broad velvety black, often reddishly shimmering, frontal stripe, which is not broader at the anterior end than the bases of the antennæ, but becomes so very much broader above that the light dustiness of the sides is entirely obliterated, the abdomen gradually becoming darker. The shimmering areas of the separate segments generally brownish. All the other parts are the same as in the male. Mature insect 6–7 mm. in length, 13–15 mm. across the wings" (Fig. 116).

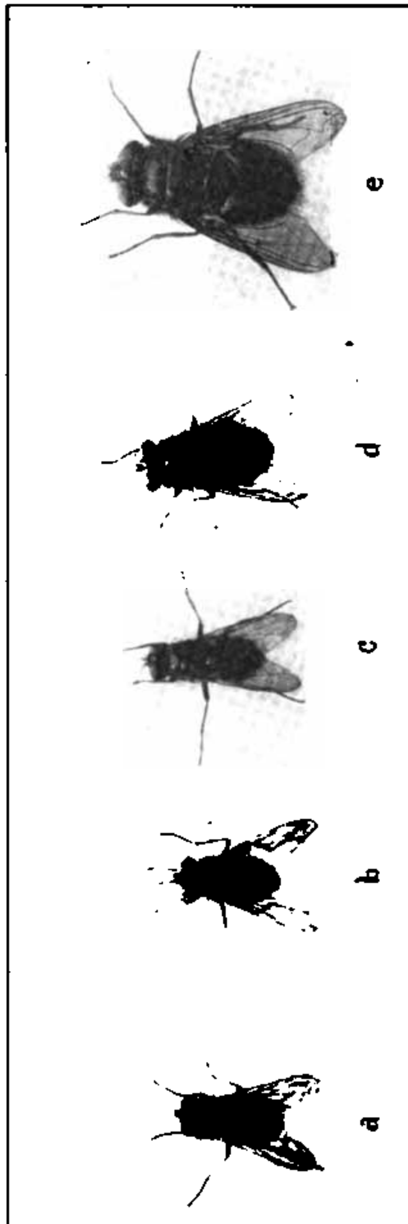


Fig. 117. — Flies commonly seen indoors: (a) the house fly (*Musca domestica*), (b) the stable fly (*Stomoxys calcitrans*), (c) an anthomyid fly, (d) the greenbottle fly (*Lucilia cæsar*), (e) the bluebottle fly (*Calliphora vomitoria*). × 2.

Why called House Fly. — Out of a total of 23,087 flies collected by Howard [1] in dining rooms in different parts of the country 22,808 or 98 per cent of the whole number were *Musca domestica*. Again out of a total of 294 flies collected by the writer, representing the entire fly population of one house, 202 or 94.4 per cent were *Musca domestica*. Thus the term *common house fly* is not misapplied. Several of the commoner species of flies found indoors are shown in the accompanying illustration (Fig. 117).

Distribution of Sexes. — In order to determine the distribution of the sexes, observations were made

[1] Howard, L. O., 1900. A Contribution to the Study of the Insect Fauna of Human Excrement. Proc. Wash. Acad. of Sciences, Vol. II, Dec. 28, pp. 541–604.

under two different conditions, viz. first, six sweepings with an insect net were made over a horse-manure pile on which many flies had gathered (the results are shown in Table VI); second, all but half a dozen flies were collected in one house, giving a fairly representative lot for indoors, even under screened conditions (Table VII).

TABLE VI

Showing Results with Regard to Sex and Species in Six Sweepings from a Horse Manure Pile on May 19, 1909

	First		Second		Third		Fourth		Fifth		Sixth		Total	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
House fly (*Musca domestica*)	7	153	4	81	3	64	9	77	4	210	5	112	32	697
Muscina sp.	2	6	0	7	0	5	2	5	3	10	1	4	8	37
Blowfly (*Calliphora* sp.)	2	2	0	1	1	0	0	0	0	0	1	0	3	3
Lucilia cæsar	0	1	0	1	0	1	0	1	0	0	0	0	0	4
Other species	1	4	0	4	2	1	4	2	4	2	2	0	13	13
Totals	12	126	4	94	6	71	15	85	11	222	9	116	56	754

TABLE VII

Showing Number of Individuals Collected in a Screened Dwelling June 1, 1909, Representing the Entire Fly Population of the Same

	♂	♀
House fly (*Musca domestica*)	86	116
Muscina sp.	3	1
Homalomyia sp.	5	0
Calliphora sp.	1	2
Totals	95	119

Explanation and Comparison of Tables VI and VII. — These two tables give us some information as to the relative abundance of the house fly, and the distribution of the sexes. Table VI shows clearly that of those flies which frequent both the manure pile and the home, the house fly (*Musca domestica*) composes 90 per cent, and that of the total collected, over 95 per cent (95.4 per cent) were females. Thus, it is clear that it is the "instinct" to oviposit (to lay eggs) that has mainly attracted these insects to the manure. In fact, fresher parts of the manure pile are often literally white with house-fly eggs in countless numbers. Observations made in the near vicinity of the manure piles proved that certainly the same percentage (over 95 per cent) of the flies clinging to the walls of the stable, boxes and so on were males.

That the number of males and females in the house fly is normally about equal is evidenced by the fact that of a total of 264 pupæ collected indiscriminately and allowed to emerge in the laboratory, 129 were males and 135 were females. The author has, however, made observations on certain flesh flies, *Lucilia cæsar* Linn. and *Calliphora vomitoria* Linn., which indicate that the factor of underfeeding must be considered in this connection. From a large amount of unpublished data, it is evident that underfeeding results in the emergence of a greater percentage of males. This does not imply, however, that sex is influenced by feeding; it only indicates that cutting short on food supply destroys the larval females first. Feeding experiments, not yet complete, on the house fly indicate that the same holds true here, but also that this insect is not so plastic as the flesh fly, hence does not vary so greatly in size and dies more easily when underfed.

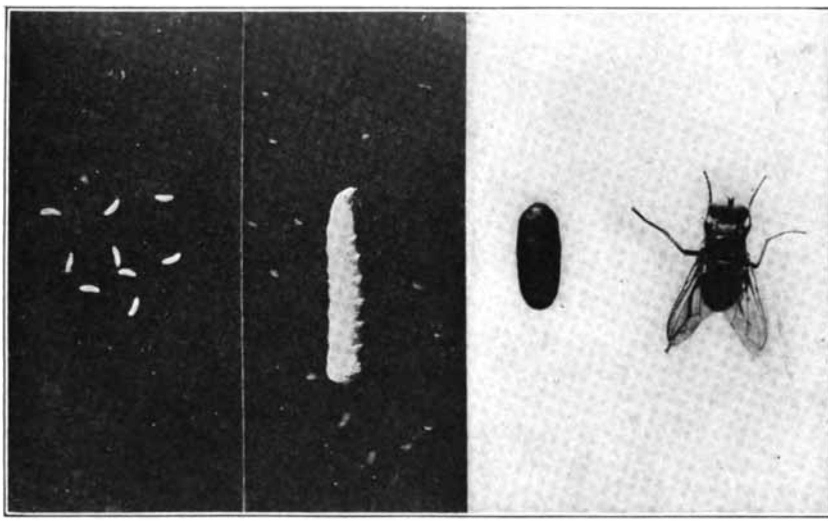


FIG. 118. — Life history of common house fly. (*a*) eggs; (*b*) larva; (*c*) pupa; (*d*) imago or adult. × 2.

Of the total number of house flies (202) collected indoors (June, 1909), representing all but perhaps six of the total number in that particular house, 57 per cent were females, showing nearly equal distribution for the sexes. This would, it seems, indicate that males and females are equally attracted to the house by odors issuing therefrom.

Life History. — The house fly passes through a complex metamorphosis (Fig. 118), *i.e.* egg, larva (maggot), pupa (resting stage) and imago or full-grown winged insect.

From 75 to 150 eggs are deposited singly, piling up in masses, and there are usually several (2 to 4) such layings at intervals of three or four days. Female flies begin depositing eggs from nine to twelve days after emerging from the pupa case. Excrementous material, especially of the horse (Figs. 119–120), is the favorite material upon which the eggs are deposited and upon which the larvæ feed. Other suitable situations are kitchen refuse, brewer's grain and other decaying vegetable matter. Where the city garbage is carefully disposed of with only ordinary attention to horse

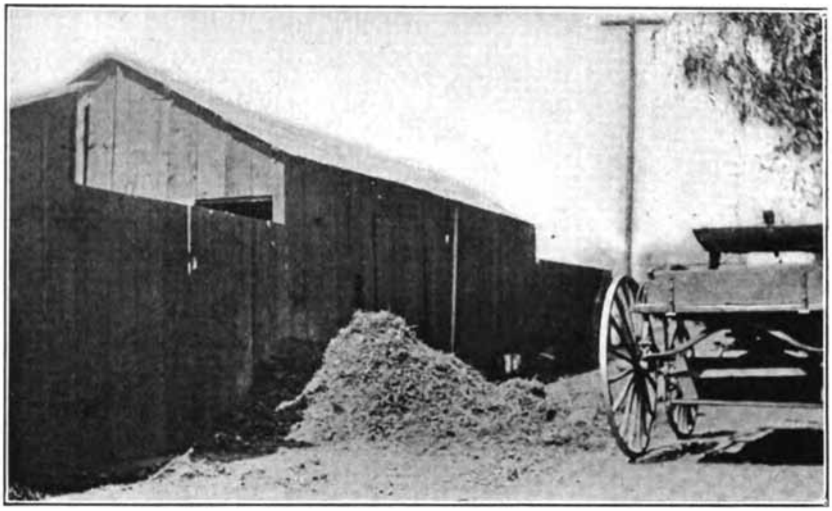


FIG. 119. — A typical rural fly breeding place, — the everlasting manure pile. The principal menace is the fresh, warm manure added on top daily.

FIG. 120. — Fly maggots will be found in abundance in similar manure piles. This is surely not sufficiently ornamental to maintain indefinitely, nor will it improve the health of the neighbors.

manure, it seems quite safe to say that 95 per cent of the house flies are bred in the latter. The house fly does not breed as abundantly in cow manure, although plentifully enough to take such material into consideration, especially when it occurs in piles mixed with straw. The eggs of the house fly hatch in from twelve to twenty-four hours; the newly hatched larvæ begin feeding at once and grow rapidly.

To gain an estimate of the number of larvæ developing in an average horse-manure pile, samples were taken after four days' exposure to flies, with the following results: first sample (4 lbs.) contained 6873 larvæ; second sample (4 lbs.), 1142; third sample (4 lbs.), 1585; fourth sample (3 lbs.), 682; total 10,282 larvæ in 15 pounds. All of the larvæ were quite or nearly full grown. This gives an average of 685 larvæ per pound. The weight of the entire pile was estimated at not less than 1000 pounds, of which certainly two thirds was infested. A little arithmetic gives us the astonishing estimate of 455,525 larvæ (685 × 665), or in round numbers 450,000, *i.e.* about 900,000 larvæ per ton of manure after only four days' standing. This particular manure pile (not from a livery stable, either) was only one of many known to exist in various parts of the city. No wonder flies fairly swarm in the vicinity of these choice ornaments!

The larval stage is the growing period of the fly, and the size of the adult will depend entirely upon the size that the larva attains. An underfed larva will result in an undersized adult. The growing stage requires from four to six days, after which the maggots often crawl away from their breeding place, many of them burrowing into the loose ground just beneath the manure pile, or under boards or stones, or into dry manure collected under platforms and the like. (One and three fourths pounds of dry manure, taken from beneath a platform, contained 2561 pupæ). The larvæ often pass three or four days in the prepupal or migrating stage before actually pupating; but in a given set of individuals under similar conditions the various stages are remarkably similar in duration, — when one pupates, the rest will certainly follow in short order, and when one emerges, others quickly appear. The average time required for development from the egg to the imago is differently estimated by various observers, inasmuch as temperature greatly influences the time required. Packard (1874) gives the time at from ten to fourteen days, Howard (1906), at Washington, D.C., as ten days. In Berkeley, California, where the weather is uniformly cool (rarely above 80° F. and a mean of 48° F. during the winter months), the life cycle is completed usually in from fourteen to eighteen days, less often in twelve days. At a maintained temperature of 30° C. the minimum time required for complete metamorphosis is nine and one third days. Prolonged cool weather or artificially cooled environment results in greater retardation. Even allowing for such retardation, the number of generations produced during the summer is quite large, and in California (Berkeley) I have seen house flies emerging from their breeding places during every month of the winter season. This latter fact lends even greater importance to a house-fly campaign. In early March a veritable pest of flies was encountered while on a trip through the Imperial Valley (California).

When the fly emerges from the pupa case with fully developed wings, it is as large as it will ever be, except in expansion and addition in weight, due to stomach contents or development of eggs in the female. This explains why no young house flies are seen (young in the sense of being small). The little flies upon the windows are not "baby" flies, but belong to another species, also adult. One can easily influence the size of a fly by underfeeding it in the larval stage, as illustrated in Fig. 121 (see Herms,[1] 1907). The question has been asked, "Why are all house flies so nearly of one size?" This is not altogether true. There are some undersized house flies, but the great majority of the larvæ or maggots find ample food for optimum development. Furthermore, experiments show that the house fly is not as plastic in respect to food conditions as the flesh fly; in other words, larvæ which are underfed perish easily.

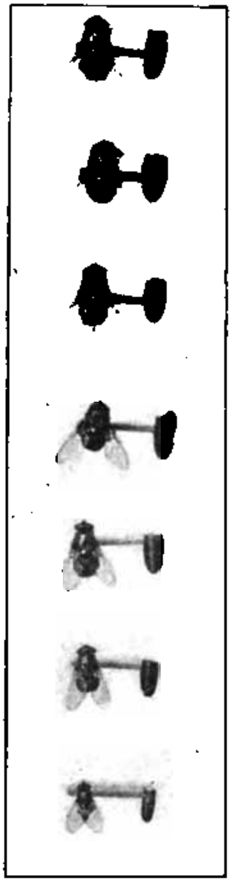


FIG. 121. — Illustrating the effect that underfeeding the larva has on the size of the adult fly (*Lucilia cæsar*). Overfeeding, if it does not result fatally, does not increase the size of the fly over the optimum, as may be seen by the uppermost individual, which is the same size as the next lower individual or optimum. Each of the next lower individuals is the result of decreasing the time of feeding by six hours. These results are based on a large number of individuals in each case. × 1.

House flies reach sexual maturity in three or four days and begin to deposit eggs on the ninth day after emergence from the pupa. Sunshine stimulates their breeding habits.

Estimating that one adult fly deposits from 120 to 150 eggs with at least six lots at intervals of from three to four days, Hodge[2] gives us the following astounding statement: "A pair of flies beginning operations in April may be progenitors, if all were to live, of 191,010,000,000,000,000,000 flies by August. Allowing one eighth of a cubic inch to a fly, this number would cover the earth 47 feet deep."

Influence of Temperature on Life History. — While conducting an extensive series of experiments in which many hundreds of house flies were used in all stages, a record was made of the temperature at which the containers were kept. Ordinarily not more than one to three quarts of manure were used for the growing maggots, hence the temperature of the environment did not differ widely from that of the manure. The temperature

[1] Herms, W. B., 1907. An Ecological and Experimental Study of Sarcophagidæ. Journ. Exp. Zool., Vol. IV, No. 1, pp. 45–83.

[2] Hodge, C. F., 1911. Nature and Culture, July, 1911.

of an average manure pile to which material is added daily varies from 18° C. to 66° C. Young growing larvæ are most numerous at temperatures varying from 45° to 55°. Below 45° half-grown and full-grown larvæ occur and above 55° the temperature seems to become too great.

From the following table it will be seen that temperature influences the time required for the development from egg to imago very materially, but nevertheless with an average outdoor temperature of 18° C. flies ordinarily require only from twelve to fourteen days to pass through the same stages; this is of course due to the higher temperature of the manure pile, as already indicated above. The shortest time required for complete metamorphosis is seen to be nine and one third days.

TABLE VIII

Showing Influence of Temperature on the Length of Life History of Musca Domestica

The insects were kept at the temperature indicated from egg to emergence of the imago. The average temperature is here given, the variation from the average was probably not more than ± 1°. Temperature of the air and not of the manure is here considered.

	16° C		18° C		20° C		25° C		30° C	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Egg stage	36 hrs.	40 hrs.	27 hrs.	30 hrs.	20 hrs.	30 hrs.	12 hrs.	20 hrs.	8 hrs.	12 hrs.
Larval stage	11 ds.	26 ds.	10 ds.	14 ds.	8 ds.	10 ds.	7 ds.	8 ds.	5 ds.	6 ds.
Pupa stage	18 ds.	21 ds.	12 ds.	15 ds.	10 ds.	11 ds.	7 ds.	9 ds.	4 ds.	5 ds.
Total time required from egg to imago	40½ ds.	48⅔ ds.	23⅛ ds.	30¼ ds.	18⅚ ds.	22¼ ds.	14½ ds.	17⅚ ds.	9⅓ ds.	11½ ds.
Average time required to develop from egg to imago	44.8 days		26.7 days		20.5 days		16.1 days		10.4 days	

Other Breeding Places. — Stable yards and empty town lots used for horses are often a source of many flies. Here the droppings from the horses accumulate and are kept moist by urine, thus affording good breeding places (Fig. 122). *The stable yard and town lot used for horses must not be overlooked in the campaign against the house fly.* Merely sweeping up the manure with a broom after the removal of the manure pile or superficial shoveling without scraping up the loose earth will not remedy the matter entirely. It must be borne in mind that when the larvæ have fed sufficiently for full growth, that is, from four to five days, they crawl into the loose earth underneath the manure pile (often great pockets of larvæ may be found thus), or they wander to loose débris in the immediate vicinity; many, of course, remain in the drier portions of the manure pile to complete their life cycle. Thousands of pupæ (recognized as chestnut-colored, barrel-shaped objects) were taken by the writer in one instance from beneath a platform leading into a stable. Therefore, when cleaning up, such conditions and situations must also be taken into account.

Human excrement, if left uncovered, furnishes another good breeding ground for the house fly. Indiscriminate defecation in alley ways and out-of-the-way places should be considered a misdemeanor punishable by a heavy fine, for the reason that house flies may breed in human excrement, and especially because of the very great danger of disease transmission by the flies. In communities where there is no sewer system, sanitary fly-tight privies should be required by ordinance (see next chapter).

Where dairy cattle are fed on brewer's grain the waste is usually

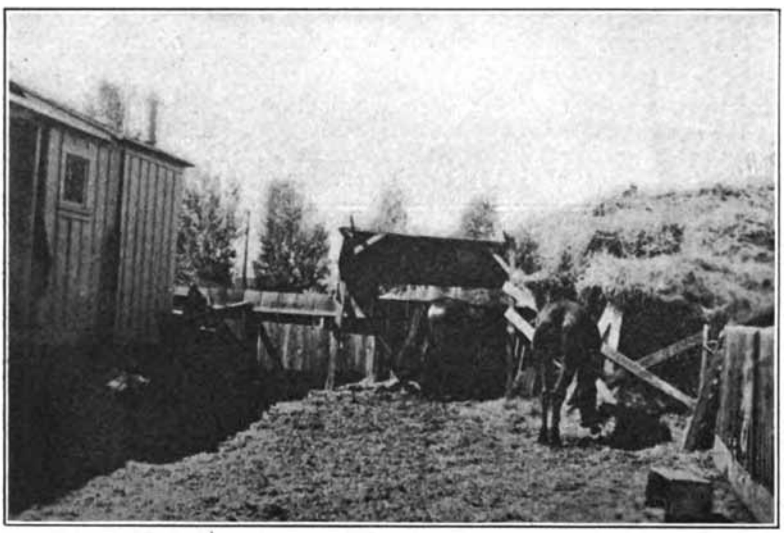


Fig. 122. — A manure-covered corral kept moist by urine from the horses forms an important breeding place for both house flies and stable flies.

thrown away in small heaps in a near-by field, thus affording a famous breeding place for flies. The writer has found that such conditions often explain the great abundance of flies about certain certified dairies, otherwise in excellent condition. All wastes of this kind should be spread out thin so that the material dries out quickly, thus preventing the development of flies.

Guinea pig pens, rabbit pens and chicken coops may become prolific breeders of flies if they are not carefully cleaned.

Kitchen refuse (Fig. 123), decaying fruit, garbage dumps, in fact any organic material that is beginning to decompose, — all afford breeding places for the house fly. But the source of the fly as a real nuisance is essentially the horse-manure pile.

Range of Flight. — Ordinarily under city conditions it may be safely said that where flies are abundant they have been bred in the same city block or one immediately adjacent. The house fly can, however, use its wings effectively and may be carried by the wind, though it usually seeks protection very quickly when a strong breeze blows. Where houses are situated close together flies have the opportunity to travel considerable distances by easy flights and they are often carried on meat and milk delivery wagons, animals, etc.

In a most illuminating experiment by Copeman[1] *et al.*, it has been shown that house flies may invade a community at a distance of from 300 yards to 17,000 yards from their breeding place; in this case a refuse heap.

Longevity of Flies. — In order to determine the longevity of flies

Fig. 123. — A poor excuse for a fly-tight garbage can. This should be regulated by ordinance.

it is necessary to keep the same individual under observation from the time of emergence from the pupa to the time of death. The writer has done this by keeping each pupa in a separate vial, noting the time of emergence to the hour and spotting each fly lightly with Chinese white dorsally on the thorax. The spots can be arranged singly and in combination so that many different flies can be kept under observation at the same time. After marking, the flies were liberated in bobbinet-covered cages (size of cages never more than 8″ × 10″ × 18″). Each cage was provided with sugar water and a receptacle of horse manure. A full set of experiments under sufficiently varying conditions indicate an average life of close to thirty days with a maximum life of something

[1] Copeman, Howlett and Merriman, 1911. In reports to the local Government Board of Public Health and Medical Subjects. New Series No. 53, Report No. 4 on Flies as Carriers of Infection (London).

over sixty days during the summer months. In hibernation flies may live over winter, *i.e.* from October to April, which is the case in our Eastern and Central states. In California, flies emerge from their pupa cases throughout the winter, and their life history is then considerably longer than in summer.

Dusting flies with foreign substances for longevity experiments is not satisfactory, inasmuch as they easily succumb to its effects or are certainly not normal.

Relation to Light. — In determining methods of control the normal behavior of organisms under natural stimuli should be taken into account and applied wherever possible. The better acquainted we are with the normal behavior of any organism, including the life history, the better able are we to cope with it.

The larvæ of the house fly when normal respond negatively to light upward of .00098 C. M., *i.e.* crawl away from the source of light and into darker areas. This reaction is useful to the larvæ because light and its heating or desiccating effect is injurious both directly and indirectly, — the latter because sunlight dries out the food material (manure) unless heaped up, and dry manure is unfavorable for the growth of the larvæ.

On the other hand, the adult flies respond positively to light, going toward the source of light. This reaction is less pronounced in the females, as may be seen from the following table (Table IX).

TABLE IX

Showing the Response of Adult House Flies to Light, under Various Intensities

The source of light in all cases was an incandescent lamp; the several intensities were secured by means of diaphragms in a low-intensity dark box such as has been described by the author (*loc. cit.* 1911).

Intensity	Sex	No. of Trials	Average Time Required for Response	Per Cent of Responses under Three Seconds	Character of Response			Percentage of Positive Reactions
					Toward	Away	Indiff.	
256 C. M.	both	25	55.4 sec.	32 %	19	6	0	76 %
.2533 C. M.	male	50	8.86 sec.	62 %	58	2	0	97 %
.2533 C. M.	female	50	25.44 sec.	50 %	44	2	4	88 %
.0633 C. M.	both	50	24.68 sec.	26 %	41	3	6	82 %

From the above table it must be concluded that the house fly responds positively to light (goes toward the source of light), even in very low intensities, at least as low as .0055 C. M. and that the male is far more responsive to this stimulus than is the female.

The female is less reactive to light and more reactive to chemical stimuli such as odors, which enable her to find the proper place for the deposition of eggs and food for the larvæ. Because of the more or less pronounced relation to light, manures deposited in dark places are less likely to breed flies. Flies can commonly be observed coming to rest in sunny spots in preference to shade, shunning the shadows.

Large areas of light are always preferred to small areas of light even though the intensity is the same. The following experiment is evidence. Two areas of light with a ratio of 1 : 3000 and a light intensity of 7.25 candle meters were placed opposite each other at a distance of one meter, the experimental room being otherwise completely darkened and painted dead black. Fifty flies were tested, giving each fly five trials midway between the light areas. Out of 250 trials 149 were toward the larger area, 93 toward the lesser and 8 were indifferent, *i.e.* 59.6 per cent toward the larger. This experiment shows that the flies respond positively to light and select the larger area by preference. Whether this indicates a degree of image-forming powers or not need not be considered here, but the writer [1] has found that certain flesh flies also respond more readily to the larger area, that is a response of 74 per cent, and Cole [2] found that the mourning cloak butterfly shows a response of 87.2 per cent.

The response to light can be made use of in a practical way, first by placing the stable manures in which the flies breed in darker portions of the stable so that the light reactions of the flies will take them away from the manure and toward the source of light; secondly, manure boxes should be so constructed that flies finding their way into the box or developing therein are afforded an opportunity to fly toward a light opening which leads into a fly trap.

Economic Considerations. — Aside from the loss of life, through typhoid fever and diseases carried wholly or in part by the fly, an economic loss of importance, the annual loss to civilized man through the direct agency of the house fly must reach astonishing proportions. Dr. L. O. Howard estimates the cost of screening at over ten millions of dollars per annum for the United States, and the writer has estimated the cost of fly traps, sticky fly paper and fly poison at more than two millions of dollars annually. If this enormous amount were spent during only one year in controlling the fly at the right end of its life history, a second year would find a saving of several millions of dollars, not to mention the lives that have been spared and the comfort wrought.

Relation to Disease. — We should be familiar with the actual method of disease transmission by the house fly. Some insects, as already described, act as intermediate host for pathogenic organisms, which

[1] Herms, W. B., 1911. The Photic Reactions of Sarcophagid Flies, especially *Lucilia cæsar* Linn. and *Calliphora vomitoria* Linn. Journ. Exp. Zool., Vol. X, No. 2, pp. 167–226.

[2] Cole, Leon J., 1907. An experimental study of the image-forming powers of various types of eyes. Proc. Amer. Acad. Arts & Sci., Vol. 42, No. 16, pp. 335–417.

latter cannot exist sexually and be transmitted without the insect, *e.g.* the malarial fever parasite (*Plasmodium vivax* and other species), which passes part of its life history in the body of the Anopheles mosquito. The house fly, as far as known, is not an intermediate host necessary to the life of a pathogenic organism of humans, but is by accident of habit

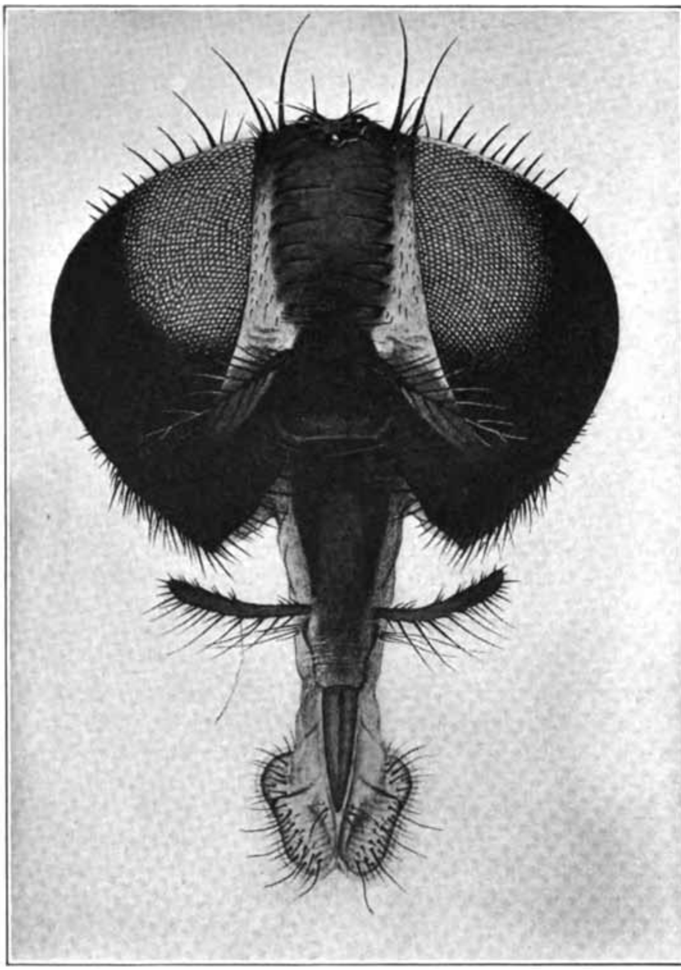


FIG. 124. — Head of the common house fly, front view. (Much enlarged.)

and structure one of the most important and dangerous of disease-transmitting insects. In habit the house fly is revoltingly filthy, feeding indiscriminately on excrement of all kinds, on vomit and sputum, and is, on the other hand, equally attracted to the daintiest food of man, and will, if unhindered, pass back and forth between the two extremes.

The house fly's proboscis (Fig. 124) is provided with a profusion of fine hairs which serve as collectors of germs and filth; the foot (Fig. 125) of the fly when examined under the microscope presents an astonishing complexity of structure. Each of the six feet is equally fitted with bristly structures and pads, which latter secrete a sticky material, adding thus to the collecting powers. This structural condition, added to the natural vile habits of the house fly, completes its requirements as a transmitter of infectious diseases of certain types.

This creature has long been known to contaminate food, but has, nevertheless, been regarded as a scavenger, and thus as a real servant

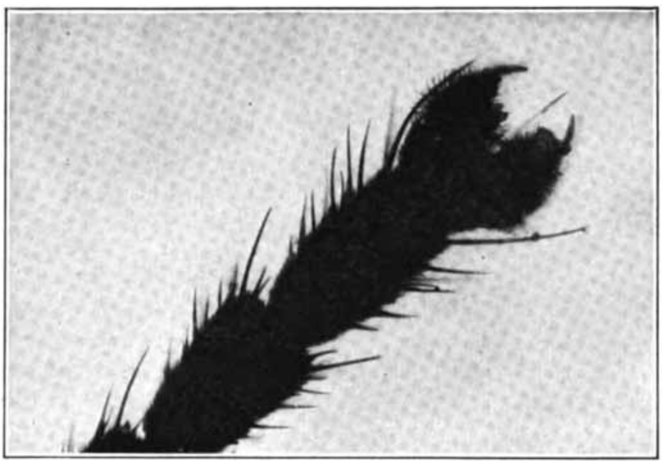


FIG. 125. — Foot of the common house fly. (Much enlarged.)

of man; but if there remains any doubt in the mind of the reader, after reading what follows, as to the necessity of getting rid of this wolf in sheep's clothing, let him take the time to make a few careful observations for himself.

Circumstantial evidence against the house fly as a transmitter of such infectious diseases as typhoid fever, tuberculosis, dysentery and cholera, is complete as summed up thus: First, it possesses the best possible structures for the conveyance of "germs" and filth; second, it possesses the habit of feeding on excrement, vomit and sputum; third, the causative organisms ("germs") of the above-named diseases may be present in the matter mentioned in the second clause; fourth, the house fly is the principal fly found in dwellings, alighting on the prepared food of man, or on food products in grocery stores, fruit stands and meat markets.

Experimental evidence that the house fly actually does carry bacteria on its mouth parts and feet and in its intestinal tract is not wanting. To illustrate, the following simple experiment may be cited.

In order to show that the house fly (*Musca domestica*) can carry "germs" of a known kind, a partially sterilized fly was placed in a test tube containing a culture of *Staphylococcus aureus*. After walking about in this tube and becoming contaminated with the *Staphylococci*, the fly was transferred to a sterile agar-agar plate upon which it was allowed to crawl about for three minutes. The plate was then incubated for twenty-four hours, after which it was examined and photographed (Fig. 126).

The photograph shows the trail of the fly as it had walked about. Every place that the foot touched is plainly marked by a vigorous bacterial growth. That the fly cannot easily get rid of all the bacteria on its feet is also illustrated by this photograph, inasmuch as three minutes spent crawling about on the agar plate did not apparently lessen the growth-vigor of bacteria deposited, and a second plate of agar-agar contaminated by the same fly immediately after exposure of the first plate gave equally astonishing results. The same experiment was performed, using *Bacillus prodigeosus* with even more pronounced results. These experiments were repeated several times with like effect.

FIG. 126. — Cultures of *Staphylococcus aureus* transferred by a house fly to a sterile agar-agar plate upon which it was allowed to crawl for three minutes. Incubation period, 24 hours.

A second series of experiments was carried on as follows: During the middle of May (1909) house flies were captured in various parts of Berkeley, placed at once in sterilized vials, and in the laboratory placed under bell jars with agar-agar plates, all under sterilized conditions. After the flies had crawled about on the culture media, the latter were incubated for twenty-four hours. In every case but one a strong growth of bacteria appeared. This one was incubated longer and after forty hours four centers of infection appeared. This fly had been taken on a sunny wall on one of the main streets, and having been under observation in this position for a long time (as reported by the assistant) it was first supposed that the action of the sunlight had sterilized it. This series of experiments included flies taken from a number of situations, namely, principal thoroughfares, sunny walls, street corners, manure piles and the dining room. Without exception the flies were laden with bacteria, and in all cases the greatest care was exercised not to introduce accidental infection to the culture plates.

Probably the most accurate study of these factors was carried on by Esten and Mason [1] on the *Sources of Bacteria in Milk* and certainly most striking facts were revealed. The following table (Table X) and attached remarks are taken from that publication, and need no further comment or explanation.

"From the following table the bacterial population of 414 flies is pretty well represented. The domestic fly is passing from a disgusting nuisance and troublesome pest to a reputation of being a dangerous enemy to human health. . . . The numbers of bacteria on a single fly may range all the way from 550 to 6,600,000. Early in the fly season the numbers of bacteria on flies are comparatively very small, while later the numbers are comparatively very large. The place where flies live also determines largely the number that they carry. *The average for 414 flies was about one and one fourth million bacteria on each.* It hardly seems possible for so small a bit of life to carry so large a number of organisms. . . . The objectionable class coliaerogenes type was two and one half times as abundant as the favorable acid type."

From the experiments previously cited it may be seen that the fly becomes infected by walking over infective materials, both its feet and wings becoming contaminated. The intestinal contents of flies become infected by feeding on infective material, and bacteria are dejected in the fly "specks." It furthermore seems plausible that flies might become infected in the larval stage by developing in fecal matter and that the newly emerged flies would already be dangerous. Under experimental conditions Graham-Smith [2] has produced infected blowflies by feeding the larvæ on meat infected with spores of *Bacillus anthracis*. He found that the blowflies remained heavily infected for at least two days after emerging and that the bacillus could be cultivated either from the limbs or intestinal contents of the flies more than fifteen or nineteen days old.

Human foods are infected by flies primarily by direct contact through the touch of feet, proboscides and wings; and secondly, through fly "specks" (feces); and finally, flies grossly infect liquids by accidentally dropping into the fluid, — this is especially true of milk.

The opportunity for flies to become infected is so great in all communities, even the most sanitary, that no fly should be trusted to alight on food prepared for human consumption. The following quotation

[1] Esten and Mason, 1908. Sources of Bacteria in Milk. Storrs Agric. Exp. Sta., Bull. No. 51.

[2] Graham-Smith, G. S., 1911. Further observations on the ways in which artificially infected flies carry and distribute pathogenic and other bacteria. Reports of the local Government Board on Public Health and Medical Subjects. (New Series No. 53.) Further Reports No. 4, pp. 31–48.

TABLE X

SOURCE OF BACTERIA FROM FLIES

1907	Source	Total Number	Total Acid Bacteria	Rapid Liquefying Bacteria	Slow Liquefying Bacteria	Bacterium lactis acidi, Group A, Class 1	Coli-aerogenes, Group A, Class 2
July 27	[a] 1 fly. Bacteriological laboratory	3,150	250	600	100	—	—
July 27	[b] 1 fly. Bacteriological laboratory	550	100	—	—	—	—
August 6	[c] 19 cow stable flies	7,980,000	220,000	—	20,000	—	—
	Average per fly	420,000	11,600	—	1,000	—	—
August 14	[d] 94 swill barrel flies	155,000,000	8,950,000	—	—	4,320,000	4,630,000
	Average per fly	1,660,000	95,300	—	—	46,000	49,300
August 14	[e] 144 pigpen flies	133,000,000	2,110,000	100,000	266,000	933,000	1,176,000
	Average per fly	923,000	18,700	700	1,150	6,500	12,200
September 4	[f] 18 swill barrel flies	118,800,000	40,480,000	—	14,500,000	10,480,000	30,000,000
	Average per fly	6,600,000	2,182,000	—	804,000	582,000	1,600,000
September 21	[g] 30 dwelling house flies	1,425,000	125,000	—	12,500	—	—
	Average per fly	47,580	4,167	—	417	—	—
September 21	[h] 26 dwelling house flies	22,880,000	22,596,000	120,000	34,000	—	—
	Average per fly	880,000	869,000	4,600	1,300	—	—
September 27	[i] 110 dwelling house flies	35,500,000	13,670,000	8,840,000	125,000	—	—
	Average per fly	322,700	124,200	80,300	1,100	—	—
August 20	[j] 1 large bluebottle blowfly	308,700	2,200	mould spores		—	—
	Total average of 414 flies	1,222,570	367,300	7,830	73,500	—	—
	Average per cent of 414 flies	—	30%	.6%	6%	—	—
	Average per fly of 256 flies, experiments [d], [e], [f]	3,061,000	765,000	230	268,700	211,500	553,800
	Average per cent of 256 flies, experiments [d], [e], [f]	—	25%	—	8%	7%	18%

from Nuttall,[1] whose careful judgment is here considered, is directly to the point, viz.: "It should be remembered that a fly may cause relatively gross infection of any food upon which it alights after having fed upon infective substances, be they typhoid, cholera or diarrhea stools. Not only is its exterior contaminated, but its intestine is charged with infective material in concentrated form which may be discharged undigested upon fresh food which it seeks. Consequently, the excrement voided by a single fly many contain a greater quantity of the infective agents than, for instance, a sample of infected water. In potential possibilities the droppings of one fly may, in certain circumstances, weigh in the balance as against buckets of water or of milk!"

That flies may serve as carriers of disease has long been suspected, *e.g.*: "Mercurialis (1577) considered that they carried the virus of plague from those ill or dead of plague to the food of the healthy. Sydenham (1666) remarked that if swarms of insects, especially house flies, were abundant in summer, the succeeding autumn was unhealthy. A number of authors, *e.g.*: Crawford (1808), might be cited who refer in a general way to insects, especially house flies, as carriers of infection; Moore (1853) refers to flies as possible carriers of cholera, typhoid, tuberculosis, anthrax and leprosy; Leidy (1872) refers to flies as carriers of the infection of hospital gangrene and of wound infection" (quotation from Nuttall, 1909, *loc. cit.*).

Typhoid Fever. — The causative organism (*Bacillus typhosus*) of typhoid fever belongs to the typhoid-dysentery group, and is found outside the human body "only in those situations where it could be more or less directly traced to an origin in the discharge of a typhoid patient or convalescent." Jordan[2] and others have shown that the life of this germ in the water of flowing streams is of comparatively short duration, and that multiplication does not ordinarily take place in water; indeed, a steady decline in numbers goes on. Infection caused by transmission through the air is exceedingly rare according to these authors, but soil on the contrary may become contaminated through buried human excrement, or otherwise, and continue to be a source of infection for a much longer time than water. Notwithstanding these facts, the majority of typhoid fever epidemics are traceable to water infection, but indicate fresh contamination and not one of long standing.

Within the human body the typhoid bacilli are found mainly in the intestine, also in the urinary bladder, and in the majority of cases in the blood stream. The bacilli are discharged from the body with the feces and the urine; and are often present in such discharges for a period of ten weeks, and in chronic carriers for years after recovery. An added

[1] Nuttall, G. H. F., and Jepson, F. P., 1909. The part played by *Musca domestica* and allied (non-biting) flies in the spread of infective diseases. Reports to the local Government Board of Public Health and Medical Subjects. (New Series No. 16.) London.

[2] Jordan, Edwin O., 1908. A Textbook of General Bacteriology. W. B. Saunders & Co. Philadelphia, pp. 557.

source of danger is the presence of virulent bacilli in very light cases of typhoid fever, known as "walking typhoid," where little or no precaution is exercised.

The above facts aid in interpreting the rôle of flies in typhoid transmission. Flies are attracted by excrementous matter, as has already been stated, and thus contaminate their mouth parts and feet, which, if the feces contain virulent bacilli, must now fairly reek with filth and disease. Thus equipped the fly next makes its way to the dining room, grocery store, fruit stand, etc., depositing there on the human food the infective dejecta by means of its soiled proboscis and feet. Thus, during the Spanish American war, flies with lime-covered feet were actually seen crawling over the food of the soldiers. The whitened feet were the result of lime and filth collected from the camp latrines. The depredations of typhoid fever at that time really mark the beginning of the widespread campaign against the house fly.

Jordan[1] states "not only may bacilli stick to the legs and wings of these insects, but if swallowed they may survive the passage of the alimentary tract. Typhoid bacilli have been isolated from house flies captured in houses in Chicago, in the neighborhood of badly kept privy vaults used by typhoid patients, and it has been shown experimentally that living bacilli may remain in or upon the body of flies for as long as twenty-three days after infection."

The writer's attention was at one time called to a series of sporadic cases of typhoid fever, plausibly traceable to flies, thus: a certain carpenter recently recovered from typhoid fever, resumed his work, making use of a box privy, such as is often used in connection with buildings under construction. In the immediate vicinity there lived a milk dealer, who, after washing his cans, placed them on the roof of a shed to drain. Flies are fond of milk, even highly diluted with water. The cases of typhoid fever in question were, on investigation, found to be customers of this particular dealer. The argument is good and reasonably conclusive.

The pollution of the waters of New York harbor has been made the subject of special study by Jackson.[2] In his report to the "Merchants' Association" of New York he shows that the sewage is not carried away by the tides, and "that at many points sewer outfalls have not been carried below the low-water mark, in consequence of which the solid matter from the sewers has been exposed on the shores." These deposits were found to be covered with flies, thus affording ample opportunity for the transmission of typhoid. It was, furthermore, found that the greater number of typhoid cases were found near the water front, and if

[1] Jordan, Edwin O., 1908 (*loc. cit.*).

[2] Jackson, Daniel D., 1908. Pollution of New York harbor as a menace to health by the dissemination of intestinal diseases through the agency of the common house fly. Report to the Water Pollution Committee of New York City.

the curve showing the prevalence of cases was set back to accord with the average time of infection, it coincided with the curve showing the prevalence of house flies. The fly curve, of course, also coincides with the temperature curve, but hot weather cannot account for the *dissemination* of the typhoid bacillus, nor for its presence.

Various authors at sundry times have shown experimentally that *Musca domestica* can carry *Bacillus typhosus* after having fed on contaminated material, both by contact with feet, proboscis and wings (Firth and Horrocks) [1] and *via* the digestive tract (Faichnie).

Flies captured in houses occupied by typhoid fever cases have also been shown to be infected; thus Hamilton found *B. typhosus* in five out of eighteen flies captured under the above condition in Chicago, and Ficker [2] made observations in Leipzig with similar results.

Thus the case against the house fly as a carrier of typhoid is conclusive.

Dysentery. — There are at least two varieties of dysentery; of which one is caused by a bacillar organism, as in typhoid fever, and is known as *Bacillus dysenteriæ*, and the other variety is caused by a protozoan organism (Entamœba) known as *Entamœba histolytica*. The former variety is known to be the prevalent type in temperate climates, while the latter is common in the tropics. The causative organism of both is found in great numbers in the stools of patients. The mode of infection is much the same as in typhoid fever.

Summer Diarrhea in Infants. — A type of *Bacillus dysenteriæ* is present in the stools of infants suffering from summer complaint. Thousands of infants die every summer from this disease. Howard [3] states that in 1908 the number of deaths due to summer complaint was 52,213, of which 44,521 were under two years. It is thus in the helpless months of the child's life that this disease is most dangerous. At this age the infants are greatly molested by flies (when these are present) attracted by milk vomits and especially stools, which often remain exposed for a long time and to which flies have free access. From these stools the flies travel to the child's face and mouth where they linger menacingly. Mothers who fail to protect their babies against the disease-bearing house fly are criminally exposing these innocents to deadly disease. Keep the baby well protected by screens, and if by accident a fly has fallen into the milk, it is better to throw it away. Furthermore, milk receptacles can easily be kept covered, and the fly in the milk is usually a sign of carelessness. Carefully protect nipples and nursing bottles against flies.

[1] See Nuttall, G. H. F., and Jepson, F. P., 1909. The part played by *Musca domestica* and allied (non-biting) flies in the spread of infective diseases. Reports to the Local Government Board on Public Health and Medical Subjects. New Series 16, No. 4, pp. 13–41.

[2] Nuttall and Jepson, 1909 (*loc. cit.*).

[3] Howard, L. O., 1911. The house fly, disease carrier. F. A. Stokes Co. New York, pp. xix + 312.

Nuttall in summing up the evidence against the house fly makes the following statement, "All authorities agree that flies rest under strong suspicion of serving as disseminators of diarrheal infection."

Tuberculosis. — Tuberculosis is caused by a specific organism, *Bacillus tuberculosis*, which may invade practically every organ and tissue of the human body. The lungs are commonly the seat of lesions, as are the intestines, the liver and the urogenital organs. The causative germs find their way outside the body in the sputum, the feces and the urine, depending on the location of the lesions.

In the study of transmission the considerable power of resistance which these bacilli possess is highly important. Dried phthisical sputum has been found to contain virulent bacilli after two months. Sputum has been found to contain living tubercle bacilli even after being allowed to putrefy for several weeks. The germicidal power of sunlight is very great, but according to Jordan [1] it requires from twenty to twenty-four hours' exposure to sunlight or even longer to kill the tubercle bacillus when present in sputum.

These facts are most important when, coupled with them, it is recognized that infection is commonly accomplished by way of the intestinal tract, with infected food introduced into the mouth. "Von Behring maintains that the vast majority of all cases of lung tuberculosis are of intestinal origin, and there is no doubt that pulmonary tuberculosis can originate from swallowing tubercle bacilli" (Jordan).

It has been proved beyond doubt that the house fly can carry with it in its intestinal tract the *Bacillus tuberculosis*. "The belief that flies (*Musca domestica*) which have fed on tubercular sputum may serve as carriers and disseminators of the tubercle bacillus first led Spillmann and Haushalter (1887) to investigate the problem. They examined such flies and also their excreta deposited on the walls and windows of a hospital ward, and were able to determine microscopically the presence of large numbers of tubercle bacilli, both in the intestines of the flies and their excrement" (Nuttall). Howard quotes the following from a "paper by Dr. Frederick T. Lord (1904) of Boston":

"1. Flies may ingest tubercular sputum and excrete tubercle bacilli, the virulence of which may last for at least fifteen days.

"2. The danger of human infection from tubercular flyspecks is by the injection of the specks on the food. Spontaneous liberation of tubercle bacilli from flyspecks is unlikely. If mechanically disturbed, infection of the surrounding air may occur.

"As a corollary to these conclusions it is suggested that —

"3. Tubercular material (sputum, pus from discharging sinuses, fecal matter from patients with intestinal tuberculosis, etc.) should be carefully protected from flies, lest they act as disseminators of the tubercle bacilli.

"4. During the fly season greater attention should be paid to the screening of rooms and hospital wards containing patients with tuberculosis, and laboratories where tubercular material is examined.

[1] Jordan, Edwin O., 1908 (*loc. cit.*).

"5. As these precautions would not eliminate fly infection by patients at large, foodstuffs should be protected from the flies which may already have ingested tubercular material."

The investigations by Dr. Ch. André of the University of Lyons were reported at the Anti-Tuberculosis Congress at Washington, 1908, viz.:

"Flies are active agents in the dissemination of Koch's bacillus because they are constantly going back and forth between contagious sputa and feces, and foodstuffs, especially meat, fruit, milk, etc., which they pollute by contact with their feet, and especially with their excretions.

"The experimental researches of the author show the following:

"1. Flies caught in the open air do not contain any acid-fast bacilli that could be mistaken for the bacillus of Koch.

"2. Flies that have been fed on sputum evacuate considerable quantities of bacilli in their excretions. The bacilli appear six hours after ingestion of the sputum, and some may be found as long as five days later. These flies, therefore, have plenty of time to carry these bacilli to a great distance, and to contaminate food in houses apparently protected from contagion, because not inhabited by a consumptive.

"3. Food polluted by flies that have fed on sputa contains infective bacilli and produces tuberculosis in the guinea pigs.

"4. Flies readily absorb bacilli contained in dry dust.

"5. Flies caught at random in a hospital ward produced tuberculosis in the guinea pig.

"*Practical conclusions.* — The sputa and feces of tuberculosis subjects must be disinfected; flies should be destroyed as completely as possible; foodstuffs should be protected by means of covers made of wire gauze."

Asiatic Cholera. — Asiatic cholera, as the name implies, is endemic in Asia (India), but has spread over the larger part of the world during the past century, becoming endemic in Africa and Europe. The disease relates to the intestinal tract, and is of bacterial origin (*Spirillum choleræ*). The cholera spirillum leaves the body with the stools, and infection is traceable to this source. "Upon the surface of vegetables and fruits kept in a cool moist place, experiments have shown that the spirillum may retain its vitality for from four to seven days" (Jordan).

Cholera was among the first diseases with which the house fly was associated as a carrier, and the experimental evidence is truly convincing. Tizzoni and Cattini in Bologna in 1886 isolated cholera vibrios from flies caught in cholera wards. Simmonds in 1892 captured flies in the post-mortem morgue in Hamburg and isolated cholera vibrios from these in large numbers.

There remains no doubt that flies are important carriers of cholera, and that bodies dead of cholera, stools and vomits of patients, should be protected from flies, and that foods should be most carefully screened.

Frambœsia (tropical ulcer or yaws) is caused by *Spirochæta pertenuis*. The disease is widely distributed in the tropics. The spirochætes are found in the superficial ulcers on the hands, face, feet and other parts of the body. The following quotation from Nuttall and Jepson[1] is convincing enough that *Musca domestica* is amply able to transmit this disease: "Castellani (1907) tested the matter of the fly transmission of yaws by experimental methods. He allowed *M. domestica* to feed (1) upon yaws material (scraping from slightly ulcerated papules), and (2) upon semiulcerated papules on the skin of these yaws patients. In both cases he was able to discover the *Spirochæta pertenuis* in microscopic preparations made from the flies' mouth parts and legs. Furthermore, he allowed *M. domestica* to feed on yaws material (1 and 2 as above) and afterwards transferred them to scarified areas upon the eyebrows of monkeys. Of 15 monkeys thus experimented upon three developed yaws papules at the places which had been contaminated by the flies."

Ophthalmia. — In commenting on ophthalmia as carried by flies Howard[2] has the following to say: "Dr. Lucien Howe of Buffalo informed the writer (Howard) that in his opinion the ophthalmia of the Egyptians is also transferred by flies and presumably by the house fly, and referred the writer (Howard) to a paper which he read before the Seventh International Congress of Ophthalmology at Wiesbaden in 1888. He referred to the extraordinary prevalence of purulent ophthalmia among the natives up and down the river Nile and to the extraordinary abundance of the flies in that country. He spoke of the dirty habits of the natives and their remarkable indifference to the visits of flies, not only children, but adults, allowing flies to settle in swarms about their eyes, sucking the secretions, and never making any attempt to drive them away. Doctor Howe called attention to the fact that the number of cases of this eye disease always increases when the flies are present in the greatest numbers and the eye trouble is most prevalent in the place where the flies are most numerous. In the desert, where flies are absent, eyes as a rule are unaffected. He made an examination of the flies captured upon diseased eyes and found on their feet bacteria which were similar to those found in the conjunctival secretions. Flies captured in Egypt swarming about the eyes of ophthalmia patients and sent to Washington, D.C., were identified as *Musca domestica*."

Other Diseases Carried by the House Fly. — Under certain favorable conditions it is also quite probable that the fly may be a carrier of anthrax, plague, gonorrheal infection, and possibly smallpox.

Eggs of Parasitic Worms. — The most extensive and careful work on the dispersal of eggs of parasitic worms by the house fly has been done by Nicoll[3] and the following is a summary of his investigations in that respect. Flies feed readily upon infective material such as

[1] Nuttall and Jepson, 1909 (*loc. cit.*).
[2] Howard, L. O., 1911 (*loc. cit.*).
[3] Nicoll, William (1911). "On the part played by Flies in the Dispersal of the Eggs of Parasitic Worms." Reports to the Local Government Board on Public Health and Medical Subjects (New Series, No. 53). Further Reports (No. 4) on Flies as Carriers of Infection. London.

excrement laden with eggs from parasitic worms and even upon evacuated worms. Eggs may be conveyed by flies from excrement to food in two ways, namely on the external surface of their body and in their intestines. The latter mode is practicable only when the diameter of the eggs is under .05 mm. Eggs with a diameter of up to .09 mm. may be conveyed on the external surface; however, these adhering eggs are usually gotten rid of by the fly within a short time, while those harbored in the intestine may remain there for two days or longer.

The eggs may remain alive and subsequently cause infection in either of these ways; however, this depends on their resisting powers. It was found that material containing eggs of parasites, and in particular ripe segments of tapeworms, remain a source of infection through flies as long as two weeks.

The eggs of the following parasitic worms were shown experimentally to be capable of transmission by *Musca domestica: Tænia solium, Tænia serrata, Tænia marginata, Hymenolepis nana, Dipylidium caninum, Dibothriocephalus latus* (?), *Oxyuris vermicularis, Trichuris* (*Trichocephalus*) *trichiurus*, both internally and externally, *Necator americanus, Ankylostoma caninum, Sclerostomum equinum, Ascaris megalocephala, Toxascaris limbata* (*Ascaris canis* e. p.), *Hymenolepis diminuta* externally only. No trematode parasites were experimented with and the observations of Stiles that the larval fly can ingest Ascarid eggs and pass them on to the adult fly was not confirmed.

CHAPTER XIV

HOUSE FLY CONTROL

Introduction. — Agitation for the extirpation of any given species always brings with it a wave of protest based mainly on the idea that there is a balance in nature which should not be disturbed. The wise agitator calls for *control* rather than elimination, not merely to appease the wrath of opponents, but because control is possible, while elimination of any given species is practically impossible except for some species in given isolated regions. A cosmopolitan species of such abundance and extensive breeding habits as *Musca domestica* is an object for *control* rather than one for elimination.

The house fly is regarded by many as necessary in Nature's economy, that it is most abundant where most needed. It is time and again asserted that the house fly, though admittedly a disease carrier, must be good for something, otherwise it would not be in existence, and should therefore not be molested. The following is an extract from a letter received by the writer, which illustrates well the objections frequently raised:

"DEAR SIR: I enclose a slip that I cut from a paper saying that you are down on the poor flies. Now, I would like to take their part. I have known them nigh on to thirty years, and I never knew of a sickness that could be laid to them. I know they make a lot of dirt, spoil picture frames and such, tickle your nose in the morning if you don't get up, but they make a nice food for young poultry. . . . Only a few years back they were considered a blessing, as they eat stuff that would make harm . . . they spot things, make a lot of cleaning, that keeps folks out of mischief. If mosquitoes or flies harm anyone, it's because the blood is out of order, and they had better look to it and mend their ways. . . . I think if you would get after them of your size, such as . . . and . . ., they are parasites that do more harm than insects and reptiles combined . . . so if you want to scrap go after them . . . this torturing poor helpless creatures to find ways to prolong lives that are worthless . . . we must all die some way . . . hoping you will let the flies and little things alone. . . ."

In reply to the above rather trivial objections it may be said in the first place that the house fly is by no means a good scavenger; on the contrary its function in that regard is very poor, since the material in which it breeds is not greatly reduced, and secondly there is no good excuse for the collection and prolonged exposure of fecal material and decaying kitchen refuse in which the fly breeds. Simply on the basis of human decency such refuse should not be permitted to collect and remain exposed long enough to breed flies. Domesticated animals are necessary to our present state of civilization, but our methods of stable sanitation and manure disposal are far behind the times, all but barbaric.

As innocent as flies may appear, they rank nevertheless among the most dangerous enemies of man. There is no virtue in the house fly, and there is no reason why it should continue to swarm in hordes in any civilized community. It is a poor advertisement for civilization. Dr. E. P. Felt[1] has so well said "our descendants of another century will stand in amazement at our blind tolerance of such a menace to life and happiness."

The house fly can be controlled without question. This is demonstrated by the scarcity of flies in localities where cleanliness about stables and houses prevails throughout a number of adjacent city blocks. The work of control can be greatly furthered by the individual citizen, but as is so well stated by the California State Board of Health in Bulletin No. 11 (1909), "This work can be done only by a united effort. The citizen must do the work, and should do it willingly, but, if negligent, the strong hand of the law should compel it." The citizen must, however, have instruction in the matter, because there is the greatest ignorance relative to the life history and development of the housefly and disease-transmitting insects in general. The writer finds that this ignorance is as prevalent among the educated as among the uneducated.

The main facts pertaining to development and habits indicate the most desirable control measures to be pursued. If 95 per cent of our house flies develop in horse manure, — and this is true under ordinary conditions, — the point of attack is clearly outlined.

Sanitary Stable Construction. — Since the principal breeding places of the house fly are found in and about stables, particular attention must be paid such situations with special reference to the disposal of manures and urine. In the first place the stable should have a concrete floor. A very practical consideration of this subject is to be found in Bulletin No. 97, North Dakota Agricultural Experiment Station, from which the following suggestions are largely taken. Although higher than wood in first cost, cement concrete meets the requirements of a good floor better than any other available material. Concrete floors, according to the bulletin mentioned, are considered best for several reasons. "1. They are economical because they are durable. Wooden floors last from three to five years with a maximum of about ten years, if of the best construction, while the durability of good concrete floors equals that of the building. 2. They save labor because of their evenness, which permits of thorough and easy cleaning. 3. They are sanitary not only because they can be kept clean, but because they are

[1] Felt, E. P., 1909. Control of household insects. N. Y. State Museum Bull. No. 129, pp. 5–47.

easily drained and are water-tight enough to exclude ground water and prevent the liquid manure from leaching into and polluting the soil.

"The chief objection to concrete floors are that they are cold and slippery. To the first may be replied that in reality concrete is no colder than wood subjected to the same temperature but on account of being a better conductor of heat concrete carries away the bodily heat of the animals faster if they come in direct contact with it. This is not a serious objection, for even wood is too cold for animals to lie on without bedding, which should be supplied liberally on any floor. Straw is a poor conductor of heat and if a sufficient amount of bedding is used, the bodily heat of the animals will be retained as well on concrete as on wood, which is apt to be more or less wet or soggy. A generous use of bedding is desirable not only because it adds to the comfort of the animals, but because of the increased amount of manure which in turn means increased fertility of the farm. The objection of slipperiness may be overcome by making the wearing surface scored or grooved into blocks before it has hardened. These sections made from 4 to 6 inches square furnish a good foothold for the animals and make a very neat appearance.

"The floor should be raised about one foot above the surface of the ground to insure drainage. If earth has been filled in to secure this elevation, it must be thoroughly compacted so as to prevent uneven settling and subsequent cracking of the floor. It is a good practice to make the desired fill as soon as the foundation is completed because it can be done more conveniently at that time and the fill will have proper time to settle before the floor is put on.

"Concrete stable floors should be about 5 inches thick. The lower 4 inches should be made of concrete in the proportion of one part cement, $2\frac{1}{2}$ parts clean, coarse sand and five parts screened gravel or broken stone and finished before the concrete has set, with a one-inch mortar of one part Portland cement to two parts clean and coarse, but sharp sand. If the sand or cement are not first-class, this proportion had best be changed, for horse barns at least, to one part cement to $1\frac{1}{2}$ parts sand.

"Before laying the concrete a foundation of porous material, such as cinders or gravel, should be spread evenly on the surface and thoroughly tamped down. The depth of this foundation will depend upon the drainage of the soil but where a fill of one foot of earth has been provided, as previously described, this foundation need not be more than four inches thick."

In constructing a concrete floor provision must be made to carry away the urine from the animals and water used in cleansing the floors and stalls. Suggestions from the above-named bulletin are here again useful, namely, the stall floors should be given a 1 inch drop from the manger to the manure gutter, which latter should be "6 inches deep and 14 inches wide. In order to facilitate the draining away of the liquids a 3-inch U-shaped channel is sometimes made in the bottom of the gutter next to the manure alley, but this is not necessary where a slope is given the gutter bottom. The gutter should be given a uniform fall of 3 inches to 100 feet and the floor of the manure alley should have a slope towards the gutter of 1 inch to 10 feet. A small water-tight liquid manure cistern may be provided outside the barn into which the gutter drains, but if a manure shed is used the cistern should be in the shed. The gutter should be connected to the cistern by means of a drain pipe effectively trapped like the soil pipe in a house and so arranged that the trap may be easily cleaned." In cities with sewer facilities connection is made directly with the sewer, dispensing with the manure cistern.

Often the concrete stall floors are covered with wood so that the animals do not come in direct contact with the concrete. If such superfloors are provided, they should be made of heavy two-inch strips three inches wide and as long as the stall. The strips are fastened together by crosspieces (ordinarily flat iron strips) so that a space of about one half inch remains between the strips. To facilitate ease of handling it is strongly recommended that the floor be made in two long pieces, each half the width of the stall, and fitting closely where they join. In this way the superfloor can be lifted up while the concrete is being cleaned; the crevices between the wood strips can be readily freed from manure by means of a heavy stream of water or iron rod. If the crevices are not also frequently cleaned, fly larvæ will develop there very readily.

Manure and odors of manure will attract the female flies even though the stable is somewhat dark. The writer believes that the small extra cost of screening a stable against flies is a good investment since it not only lessens the opportunity for flies to breed but also adds to the comfort of the animals.

Disposal of Manures. — Wherever horse manure is piled up in the open the opportunity is given for flies to breed. In the preceding chapter it was pointed out that an average manure pile weighing about half a ton, after an exposure of only four days harbored approximately 450,000 fly larvæ. As before stated it requires only about four days for the larvæ to reach full growth, after which they begin to migrate into the drier portions of the heap and crawl out into near-by débris, beneath platforms, etc. It is therefore imperative, if fly breeding is to be prevented, that manure be protected against flies from the beginning, or that it be rendered undesirable to flies, or that it be otherwise disposed of.

Under ordinary rural conditions the most practical method is to remove the manure to the field daily. A cart may be used for this purpose; it is daily backed up against the stable doorway, the manure thrown in and carted away at once to a field where it is scattered. This saves much time in handling and is sound agricultural practice. Since moisture and warmth are both necessary for the development of fly larvæ the scattered manure cannot serve this purpose.

If more desirable, the manure may be placed in deep narrow trenches (preferably concrete) each day and daily covered with slaked lime and earth and allowed to rot. The disadvantage is that the manure must be dug up from the trenches later when it is to be used as fertilizer. However, the former method is more practical and is highly recommended. The Wisconsin Bulletin No. 221 states: " Manure is never so valuable as when perfectly fresh, for it is impossible under the best system of management to prevent all loss of its fertilizing ingredients. For this reason, whenever possible, the manure should be hauled directly to the field and spread. The system saves time and labor as it involves handling but once. The manure will be leached by the rain and snow, nevertheless the soluble portion will be carried into the soil, where

FIG. 127. — Manure bin in a position to become a fly breeding cage, instead of a fly preventative. It is suggested that the lid be permanently closed, and an opening made directly from the stable into the bin. The manure pile adjoining the bin illustrates the manner of disposal before the bin was built.

it is needed. When spread in a thin layer, it will not heat, so there will be no loss from hot fermentation, and where manure simply dries out when spread on the ground there is no loss of valuable constituents."

The question is raised, — will not chickens eat the maggots and thus keep in check the flies in manure piled up in the barnyard? It must be considered that manure piled up sufficiently deep to permit fly larvæ to develop in it does not permit chickens to scratch their way through the heap and consequently they can only destroy a small fraction of the larvæ; and where the manure pile is low enough for chickens to scratch it over and over, the fly larvæ would not develop anyway owing to the dryness and lack of heat. Furthermore, it is not safe to permit chickens to feed on maggots owing to the fact that the larva of a common and dangerous poultry tapeworm is commonly harbored by these insects. Farmers and gardeners who wish to use "rotted" manure for fertilizing purposes should screen the heap until the "rotting" process is well under way, when fly breeding will be reduced to a minimum, or, as has already been suggested, the manure may be placed in trenches and covered with lime and earth whenever fresh manure is added or it may be stored in fly-tight composting pits.

Manure Bins. — Under city conditions it is ordinarily impracticable to remove manure from the premises daily, hence it must be

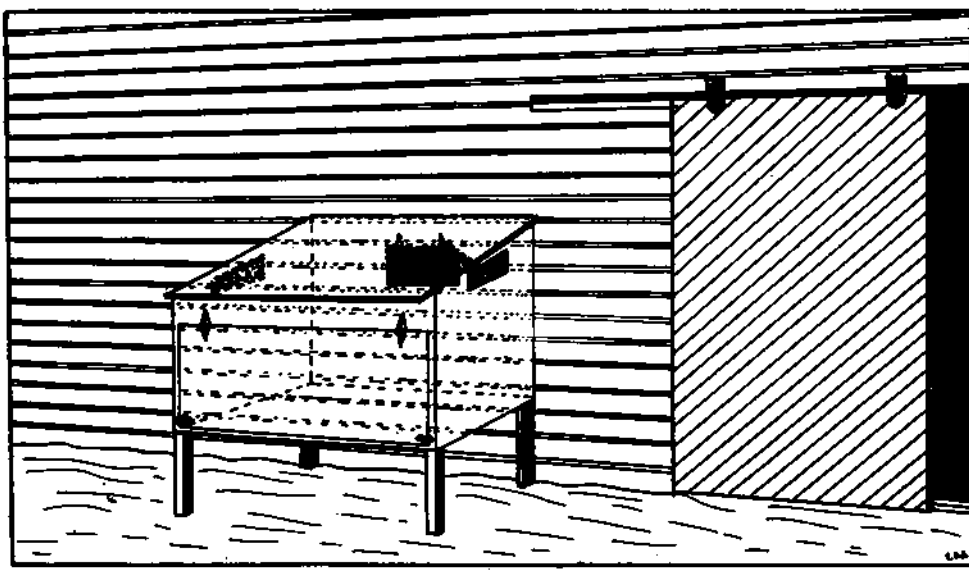


FIG. 128. — A properly constructed manure bin with opening directly from stable into bin. May or may not be elevated on legs to facilitate removal of manure to wagon. Size of bin depends on number of horses and frequency of manure removal.

stored temporarily in special receptacles or bins. Heretofore stress has been laid on *fly-tight* receptacles, but unless exceptional care is exercised in operating such receptacles, they actually become fly-breeding cages. The writer early recognized this difficulty and suggested a remedy as below described.

Fig. 127 illustrates a manure bin of the earlier type. The manure pile near by illustrates the manner of disposal before the bin was erected. In this case the lid of the bin must be kept open while the manure is being transferred to it from the stable, and during this time flies enter the box in numbers, and when the lid is closed they are trapped, deposit their eggs and soon the manure is reeking with maggots and if the bin is not cleaned out before the expiration of nine or ten days myriads of flies emerge and are liberated when the lid is opened.

The bin is built on a concrete floor to prevent rats from nesting underneath, it is painted with creosote inside and ventilation is provided for at both ends by means of screened openings. The screen should be of copper wire to prevent rapid rusting. The front of the bin is provided with a hinged door which lifts up so that the manure can easily be removed. The dimensions are approximately as follows: length, 8 ft.; width, 4 ft.; height in front, 4 ft.; height in back, 5 ft.

The size of the bin, or composting pit if this is used, depends, of course, on the number of horses stabled and length of time during which the manure remains in storage. It may be estimated that the average horse produces 1½ cubic feet of manure per day, including bedding.

To prevent the bin from becoming a fly-breeding cage, the writer recommends that the top be permanently closed, *i.e.* without a lid, and that the manure be thrown into the bin directly from the stable through a small door cut through the side of the stable into the bin near the top of the same (Fig. 128). This opening can easily be provided with a small sliding, screened door. Furthermore the bin should be built so that the small door last mentioned can be located in a dark part of the stable, thus further preventing flies from entering the bin. At a small added cost fly traps can be attached at the ventilator ends of the bin in such a manner that chance flies in the box will enter these and be entrapped. Because the flies respond to the light they will naturally gather at the ventilator ends and if the traps are baited with some material attractive to the flies, there is an added inducement to enter.

Fig. 129. — An effective combination garbage can and fly trap. (After Hodge.)

Garbage Cans. — The writer has been favorably impressed with the type of combined garbage can and fly trap invented by Professor C. F. Hodge. By his permission a diagram is here given (Fig. 129), together with his explanation of the same (see *Nature and Culture*, July, 1911), viz.: "The principle of operation is that hungry flies will crawl in toward the smell of food through any dark crack and, after feeding, will fly out toward the light. They enter the garbage can or other receptacle by smell, and attempt to leave by sight. It is necessary to have the cover about half an inch larger in diameter. Three pieces of sheet iron are soldered inside the rim, equidistant apart to hold it up a crack, and keep it spaced out from the rim of the can about one fourth of an inch all around. In a swill barrel, nails may be driven into the rim and bent over to hold the cover properly, *but direct light must not enter this crack.* Cut a hole in the cover at least three inches in diameter and fasten the trap over this opening according to plain directions sent out with each trap. With everything in the way of waste food material put into this receptacle, you establish a 'focus,' a 'vacuum cleaner' for flies, and properly managed, this will prove exterminative."

Where ordinary garbage cans are used and certainly every household should possess a garbage receptacle that can be tightly closed against flies (unless above plan is followed), it is strongly urged that all liquids be drained from the refuse before disposing of it and that the solids be wrapped in a newspaper before placing in the can. In this way fly breeding in garbage cans may be effectually prevented and an act of mercy is done the scavenger and others as well.

Garbage Collection and Disposal. — Not only must the garbage can and its proper use be insisted upon in this connection, but also the proper collection of the garbage by the scavenger. Few sights are more disgusting than that of an open garbage wagon reeking with its load of vile-smelling offal and swarming with flies. During the strawberry season it is a matter of daily occurrence in many cities to see

FIG. 130. — Flies are commonly and abundantly distributed through the community by poorly arranged garbage wagons. Properly constructed, closed, city-owned and regulated garbage wagons must take the place of the above pernicious system.

the garbage wagon (Fig. 130) traveling side by side with the strawberry wagon, flies crossing from one to the other without restriction. This is certainly revolting if not also a menace to health. Municipal collection of garbage in properly constructed city-owned garbage wagons is the only solution of the present outrageous common system.

No more sanitary way of disposing of garbage can be devised than that of incineration. The garbage *dump* will always be a fly producer, particularly if it receives manures and moist offal.

The Sanitary Privy. — The house fly breeds in enormous numbers in human excrement if given the opportunity, particularly in open, shallow privies. Not only are the newly emerging flies laden with filth, but also flies from the whole neighborhood which have congregated about such filth places, going back and forth between these and the family kitchen and dining room. This outrage against civilization calls for fly-proof privy construction. Many small communities have no sewer system, hence the use of the old-fashioned privy (Fig. 131) is still in vogue, though in many places there is now installed the septic tank system which permits of sanitary conveniences in the home at a reasonable cost. The septic tank places within the reach of all farm homes the establishment of modern sanitary conveniences in the house, free from any possibility of fly breeding. However, the appended figures of a sanitary privy suggested by the California State Board of Health Bulletin, Vol. 6, No. 6, after Stiles (Fig. 132), will furnish the reader with an adequate idea for the construction of a fly-tight privy. It must be borne in mind that simply covering the excreta

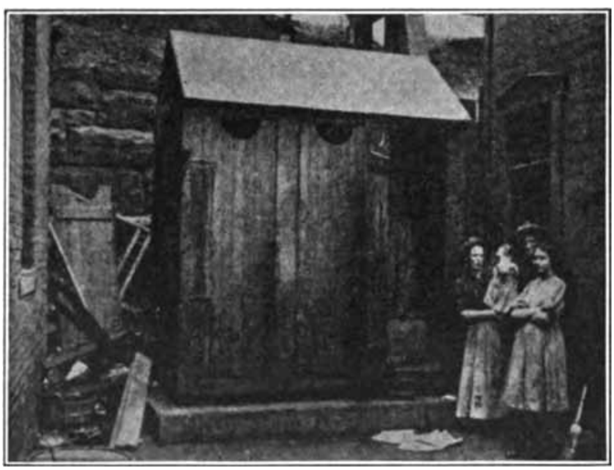


Fig. 131. — Privy, swarming with flies, adjoining kitchen door. These conditions, inviting disease and insuring the pollution of food, are practically duplicated in hundreds of towns. (By courtesy of *The Survey*.)

with dry earth does not prevent flies from breeding therein. In the absence of a fly-tight privy it is advisable to add quantities of chloride of lime, crude oil, or kerosene to the excreta two or three times a week.

Fly Traps. — Unless fly traps are used to capture the flies as they emerge from their breeding place, as already described, such measures are ordinarily only excuses for the more important cleaning-up process; the entrapped flies have ordinarily already had ample opportunity to carry filth and germs and deposit their eggs. However, traps may be useful adjuncts to other more permanent corrective measures, — the more flies captured the better, but the trapping should begin very early in the spring in order to capture the early flies which are responsible for the later multiplied millions of the same species. Many good fly traps are on the market and these may be baited with milk soaked bread, stale beer, or the juice of crabs.

Insecticides on Manure Piles. — The writer is constantly requested to recommend insecticides that may be applied to manure in order to either destroy fly larvæ or prevent fly breeding. He has for some time consistently refrained from making such recommendations, because, in the first place, such methods seem to be accepted as a substitute for cleaning up, and, in the second place, owing to the necessity for constant repetition, applications of the same would certainly be neglected. Furthermore the expense of the daily use of insecticides in efficient strengths is forbidding to the man of ordinary means.

Ordinary applications of the usual insecticides prove of no avail. The cheapest, and at the same time the most effective, preparations must be applied two to five times as strong as when used against other insects,

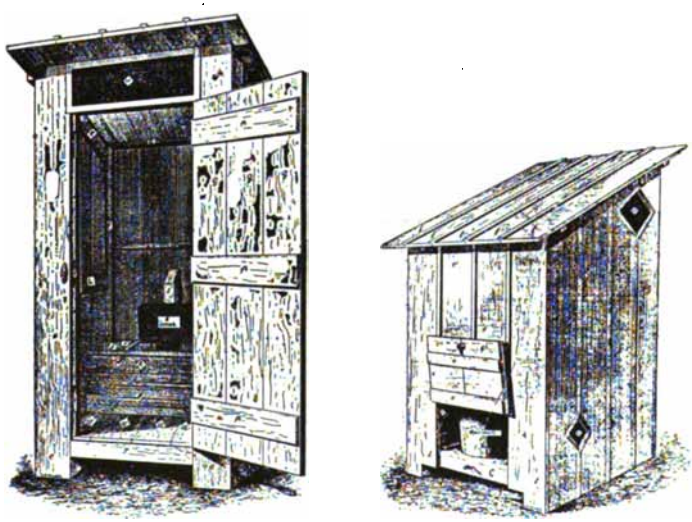


Fig. 132. — A sanitary privy, — front view to left; rear and side view to right. (After Stiles and Lumsden.)

and furthermore the larvæ cannot be easily reached, buried as they are in the straw and manure. In the face of these conditions the more reliable and really simpler methods already mentioned are recommended.

Chemicals used to destroy the larvæ may be roughly divided into two classes, viz. (1) contact poisons, and (2) stomach poisons. To the first class belong such preparations as kerosene, chloride of lime, etc. To the second class belong the arsenicals represented by arsenate of lead and paris green.

Where the manure can be spread out to a depth of about half a foot it may be drenched with a distillate petroleum, which possesses a high flash point, *i.e.* does not ignite easily, and which has the necessary insecticidal value. Kerosene Emulsion should be applied at the rate of one part of the oil to five parts of water. *If distillate oils of a low flash point are used about stables and outbuildings, the danger from fire must not be overlooked.* The manure so treated cannot be used for fertilizing purposes.

Chloride of lime, also a contact insecticide, applied liberally to the manure is effective, but, like the above, is expensive when used in proper quantities.

TABLE XI

Showing the Effect of Various Insecticides and other Materials on Fully Grown House Fly Larvæ

The larvæ were placed in shell vials, two larvæ in each, ten for each set. The vials were capped with filter paper and a strip of the same material soaked in tap water was placed inside with the larvæ. Check sets treated with tap water were run in connection with each experiment. Temperature conditions were favorable in all cases. Whenever less than 90 per cent of the check larvæ emerged as flies the entire experiment was discarded. Each material was given at least two tests, ordinarily by different persons.

Name of Material Used	Concentration	No. of Larvæ Killed	Name of Material Used	Concentration	No. of Larvæ Killed
Carbolic acid	2½%	100%	Lime sulphur	straight	0
Carbolic acid	1%	90%	Pyroligneous acid	straight	0
Creolin	2½%	100%			
Creolin	5%	100%	Boracic acid	saturated solution	100%
Creolin	10 %	100%			
Kerosene	straight	100%	Boracic acid	40% solution	90%
Kerosene emulsion	1 to 10	0%	Borax	powder	80%
Kerosene emulsion	1 to 8	50%	Formaldehyde	4%	100%
Kerosene emulsion	1 to 5	100%	Formaldehyde	2%	0
Nicotine sulphate	40%	80%	Ferric sulphate	saturated solution	10%
Nicotine sulphate	20%	80%			
Tobacco dust	high grade	0	Common salt	saturated solution	0
Ferrous sulphate	saturated solution	0–10%	Sodium cyanide	1% solution	100%
Ferrous sulphate	10%	0	Sodium cyanide	$\frac{1}{10}$ of 1%	0
Ferrous sulphate	20%	0	Pyrethrum powder	straight	80%
Potassium dichromate	saturated solution	100%	Gypsum	straight	0
Potassium dichromate	20%	100%	Carbolate of lime	straight	100%
Potassium dichromate	10%	80%			
Potassium dichromate	5%	40%	Carbolate of lime	mixed with manure	20%
Potassium dichromate	1%	30%			
Chloronaphtholeum	1 to 100	100%	Phenoco	1 to 100	20%
Chloronaphtholeum	1 to 200	100%	Phenoco	1 to 200	100%
Chloronaphtholeum	1 to 300	30%			
Chloronaphtholeum	1 to 400	0	Pyxol	1 to 200	50%
C.N.	1 to 100	100%	Pyxol	1 to 100	0
C.N.	1 to 200	100%	Pyxol	1 to 50	90%
C.N.	1 to 500	70%			

The use of arsenical poisons has not been thoroughly tested by the writer; indeed he hesitates to recommend these materials for general use because of the danger to domesticated animals in and near the barnyard; however, Newstead [1] states: "the application of paris green (poison) at the rate of two ounces to one gallon of water to either stable manure or ashpit refuse will destroy 99 per cent of the larvæ. Possibly a smaller percentage of paris green might be employed with equally good results. One per cent of crude atoxyl in water kills 100 per cent of fly larvæ." The application of either of these substances might, however, lead to serious complications and it is very doubtful whether they could be employed with safety.

In an experimental study of a large number of insecticides as applied to fly larvæ, the writer, in coöperation with several of his students, has obtained the above results (see Table XI).

The above table includes only a partial list of materials tested out in the laboratory, and indicates that there are a number of remedies heretofore advertised as efficient in the control of fly larvæ, now proved to be without virtue, among them pyroligneous acid, gypsum, and iron sulphate. On the other hand there are quite a number of materials which have proved efficient, notably carbolic acid 1 per cent to 2½ per cent, creolin 2½ to 5 per cent, kerosene emulsion 1 to 5 per cent, potassium dichromate 20 per cent, sodium cyanide (very dangerous) 1 per cent solution, chloronaphtholeum 1 to 200, "C. N." 1 to 200, and boracic acid in saturated solution. The U. S. Department of Agriculture recommends applying .62 pound borax or .75 pound calcined colemanite to every eight bushels (10 cu. ft.) of manure immediately on its removal from the barn. The borax is to be applied by means of a flour sifter to the outer edges of the pile and sprinkled with two or three gallons of water. Hellebore is also recommended.

In applying these materials and others already mentioned for the destruction of fly larvæ, two things must be borne in mind, namely (1st) that the manure pile must be drenched in order that the chemical may reach the individual larvæ, and (2d) what effect will the chemical have on the fertilizing value of the manure?

Hot Water Method.—It is, of course, well known that manure stored in tight vessels and covered well with water does not breed house flies. The writer has also carried on a number of experiments with *hot* water, particularly in such cases in which the manure is already inhabited by fly larvæ and it is desired to use the same or remove it. Water heated to 90° C. (195° F.) and applied in saturating quantities destroys all larvæ. At 85° C. and below all continue to develop.

Two objections are commonly raised against this method of treatment: (1st) that the useful bacteria are destroyed, *i.e.* that the manure is

[1] Newstead, R., 1908. Life cycle and breeding places of the common house fly (*Musca domestica* Linn.). Annals of Tropical Medicine and Parasitology, Vol. 1, No. 4, pp. 507–520.

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rendered sterile, and (2d) that all other desirable constituents are leached out by the water. These objections are not altogether well founded. Not all of the useful bacteria by any means are destroyed by the hot water and those remaining quickly multiply and soon render the manure as good as ever. In the second place the leachings may be preserved quite easily by first placing the manure in a tight shallow box similar to those used by plasterers for mixing mortar, and adding a spigot or simply boring a large hole in the bottom and inserting a plug, thus preserving the ingredients until allowed to flow out of the hole into a pail to be applied as liquid manure.

The above-described method is particularly useful to gardeners and mushroom growers who must use rotted manure, in which fly larvæ of many species occur very abundantly.

The Fly in the House (Fly Poisons).—Because of the disease-transmitting powers of flies they should be kept away from human food. Fly swatters should be used vigorously and daily. Screens must continue to be used until the community as a whole learns to apply the simple measures for the control of the fly, when screens will no longer be needed, and that time is not far off. The use of poisonous (arsenical and cobalt, etc.) preparations upon which the flies may feed is not recommended, inasmuch as the poisoned insects may drop into foods, a matter perhaps of small importance, but what is more important, many of these preparations are a menace to human life, especially to small children. The writer has found (as already suggested by others) that formaldehyde, properlv used, forms a very good substitute for arsenical or cobalt poisons. Various dilutions and combinations were tried, but a 2 per cent solution sweetened somewhat with sugar or honey (or even without sweetening) proved most desirable. Formaldehyde is inexpensive when thus used, and has the added advantage that it is relatively not poisonous to man in weak concentrations, and may, therefore, be used with little fear. It is also one of the most powerful germicides known, and is not injurious to delicate fabrics. Formaldehyde is ordinarily purchased in from 38 to 40 per cent solutions and should be diluted with water to about 2 per cent (add about twenty times as much water). The solution should be placed in shallow vessels on window sills, on the table or in the show window. It is not an easy matter to control the fly in a dining room where there are plenty of liquids for food and drink, such as water, milk, sweets, etc., hence, these should be removed or covered, for example, in the evening and the dishes of formaldehyde then put in place; the flies will drink the poison the first thing in the morning and the end will be readily accomplished. One is thus taking advantage of the fact that the fly seeks something to drink early in the morning. Placing a piece of milk-soaked bread in the dish of formaldehyde adds somewhat to the efficiency. During the day the fly poison acts best when placed in a sunny spot. For outdoor work formaldehyde is equally efficient, but must be made inaccessible to chickens, birds and other animals by screening with coarse-mesh wire.

Various fumes created by burning one or the other of the following materials will stupefy the flies,—pyrethrum powder (*Persian pyrethrum* or *Chrysanthemum cinerariafolium*), buhach, dried Jimson weed leaves (*Datura stramonium*) mixed with crystals of saltpeter (see under mosquitoes), fumes of "cresyl," etc. The fly-fighting committee of the American Civic Association recommends the following: "Heat a shovel, or any similar article, and drop thereon 20 drops of carbolic acid; the vapor kills the flies."

Other Precautions. — It is highly important that sick rooms be well screened, especially in cases of certain transmissible diseases, such as typhoid fever, tuberculosis, etc. For the protection of the outside world any flies that chance to find their way inside after the best precaution has been exercised should be killed to prevent their escape. Pus rags, bandages, sputum cloths, and the like, should not be carelessly thrown into the open garbage barrel where flies freely congregate. It may seem unnecessary to even mention these simple sanitary measures, but the writer has seen the grossest neglect in matters of this kind, even where better judgment should have prevailed.

Natural Enemies. — The most important natural enemy of the house fly is the fly fungus, *Empusa muscæ,* first described by DeGeer in 1872 (Howard) and rediscovered annually by enthusiastic human enemies of the house fly. During late summer and autumn and throughout the moist winter in California, dead flies are frequently found clinging to curtains and walls; the abdomen is usually greatly distended, showing distinct bands due to the appearance of the intersegmental tissue brought to view by the pressing apart of the darker segmental rings. The disease is commonly known as fly cholera.

This fly fungus originates from spores which, when a fly is attacked, produce hyphæ, thread-like processes which enter the body of the fly and develop a mesh work of threads, producing great distension of the fly's abdomen. This mycelium later evidently sends out hyphæ through the intersegmental tissue, which hyphæ then produce spores or conidia. The spores are then separated often with some force, and may produce a sort of "halo" about the now dead fly. Other flies thus become easily infected. The writer has lost experimental colonies of flies in great numbers in this way in less than two weeks after the appearance of the disease.

Another very common parasite of the fly is a red mite, *Acarus muscarum.* Often three or four of these mites may be seen as tiny red specks on the head, neck or thorax of the house fly. Occasionally they actually retard the fly in its flight.

When rearing house flies from pupæ collected out of doors one is frequently surprised to find that 50 per cent or more give rise to a tiny dark metallic wasp which creeps out of the pupa case through a minute hole. These are chalcidoid wasps, one species of which is known as *Nasonia brevicornis*.

While house flies are also attacked by various other natural enemies, such as spiders, robber flies, toads, lizards, etc., their generation does not seem to be greatly affected, and man must depend more and more on suppressing the breeding places of the pernicious pest or suffer the consequences.

The Community Fly Crusade. — Under city or town conditions the crusade against the fly must be backed up by the intelligent interest of the citizens. Through intelligent coöperation it should be possible to reduce the fly population of any city or town by 95 per cent during the course of a single summer, and if action is taken in the autumn to eliminate breeding places and destroy overwintering flies, the following summer could be made practically flyless.

Numerous crusades against the housefly have been conducted in many cities in the United States with good results. In each case the work has usually been begun by an organization, already in existence, such as a Women's Club, Civic Club, Chamber of Commerce and occasionally a Board of Health. Methods of procedure are usually outlined by competent Medical Entomologists, Parasitologists, Medical Officers or other individuals.

To carry out the suggested permanent preventive measures, etc., a community should, to begin with, have an appointed staff of trained inspectors, the number varying with the size of the community; four capable men working in pairs can cover considerable territory very well. No community should be without regular, trained sanitary inspectors under the direction of the Board of Health. The position of sanitary inspector should carry with it some dignity, and should be filled by men instructed in practical hygiene, including a fair knowledge of medical entomology, owing to the importance of insects in their relation to disease transmission.

The best results will always be secured when the work is done through the Board of Health with as many civic organizations, schools, clubs, etc., as possible in intelligent and systematic coöperation to spread the propaganda. The active assistance of the school children may well be enlisted for the sake of the lesson in community service. However, little can be said in favor of offering prizes for a given quantity of flies. Let the children be taught where flies originate, their habits, etc., and then let the children report the presence of flies, say by counts, in certain situations, stores, homes, etc., and locate and report breeding places particularly. There will be just as much interest and enthusiasm, the ultimate results will be better and the opportunity to *deal in flies* is not a factor, — the children are dealing in terms of cleanliness, hygiene and sanitation.

"Fly swatting" only serves to attract the attention away from the real issue, namely, the control of breeding places. However, a wise, properly guided agitation in this direction in the winter and spring would serve to reduce the early crop of flies materially, and the interest thus secured could gradually be won over to the side of civic cleanliness and the slogan will have changed from "swat the fly" to "swat the manure pile."

Communities in which a campaign against the house fly has been undertaken with a determination to win have shown that this insect can be controlled, and this without great labor and expense. The problem is simpler than many are willing to admit. Hearty coöperation is essential. Everybody is concerned, and everybody will share in the victory and share in the saving of financial and vital losses. Remember this, — *the presence of many flies always denotes a dirty environment.*

Figure 133 illustrates the type of literature used by various communities in their crusade against the fly, and Fig. 134 shows a part of the "House-fly Exhibit" at the Baby Saving Show held in Oakland, California, in 1914.

FIG. 133. — Literature, bulletins, etc., used by various communities in their crusades against the house fly.

Manure, Stable and Fly Ordinances. — Under ordinary conditions the crusade against the fly must also be a matter of ordinance backed by the intelligent interest of the citizens. One stable owner who does not

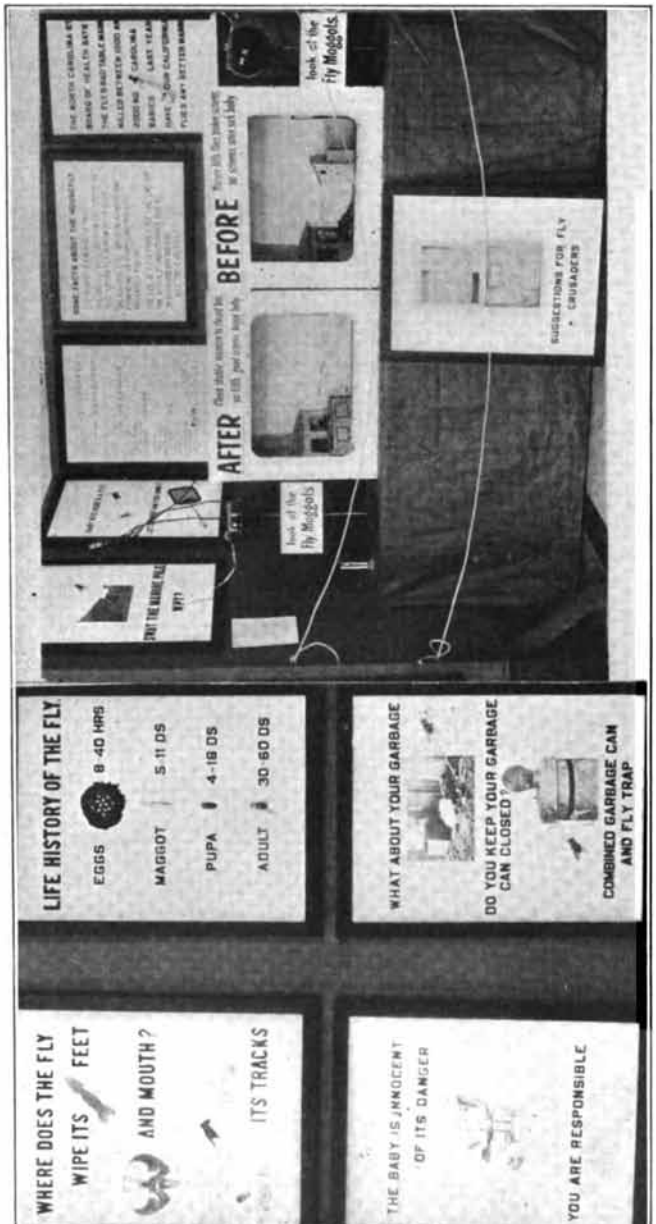

FIG. 134. — Showing a part of the "Fly Exhibit" at the Baby Saving Show held in Oakland, California.

believe in the "*notion*" that flies originate in horse manure (and there are not a few of that kind), can easily supply flies for several adjacent city blocks, hence there must be some ordinance to compel action.

Ordinances must be practical so that it is possible to comply therewith, must be constitutional and must provide for a basis for conviction, *i.e.* our newer manure ordinances will point out that the presence of fly larvæ or pupæ is sufficient evidence that the provisions of the ordinance have not been complied with.

Ordinances aimed at the fly nuisance fall under three heads, namely, (1) Stable ordinances, (2) Manure ordinances, (3) Food ordinances (protection against dust and flies).

Stable Ordinances. — The following regulations, according to Howard,[1] are in force in the District of Columbia:

"*Sec.* 18*A*. No person owning, occupying or having use of any stable, shed, pen, stall, or other place within any of the more densely populated parts of the District of Columbia, where animals of any kind are kept shall permit such stable, shed, pen, stall, or place to become or to remain filthy or unwholesome.

"*Sec.* 18*B*. No person shall use any stable, nor shall any person having the power and authority to prevent or permit any person to use any stable, within any of the more densely populated parts of the District of Columbia, after the first day of July, 1907, unless the surface of the ground beneath every stall and for a distance of four feet from the rear thereof be covered with a water-tight floor laid with such grades as will cause all fluids that fall upon it to flow as promptly as possible, if a public sewer be available, into the public sewer, and, if a public sewer be not available, to that portion of the premises where they will cause the least possible annoyance.

"*Sec.* 18*C*. Every person owning or occupying any building or part of a building within any of the more densely populated parts of the District of Columbia, where one or more horses, mules, cows, or similar animals are kept, shall maintain in connection therewith a bin or pit for the reception of manure, and, pending the removal from the premises of the manure from the animal or animals aforesaid, shall place such manure in said bin or pit. The bin or pit required by this regulation shall be located at a point as remote as practicable from any dwelling, church, school or similar structure, owned or occupied by any person or persons in the neighborhood of said bin or pit, other than the owner or occupant of the building or part of building aforesaid and as remote as practicable from any public street or avenue; shall be so constructed as to exclude rain water, and shall in all other respects be water-tight except as it may be connected with the public sewer or as other definite provisions may be made for cleaning and flushing from time to time; shall be provided with a suitable cover, and constructed so as to prevent in so far as may be practicable the ingress and egress of flies. No bin or pit shall be constructed the bottom of which is below the level of the surface of the surrounding earth unless it be of substantial masonry and connected with the public sewer. The provisions of this paragraph shall take effect from and after the expiration of three months immediately following its promulgation.

"*Sec.* 18*D*. No person owning or occupying any building or part of a building located within any of the more densely populated parts of the District of Columbia in which building or part of a building any horse, mule, cow or similar animal is kept, shall keep any manure, or permit any manure to be kept, in or upon any portion of the premises other than the bin or pit provided for that

[1] Howard, L. O., 1911. The housefly, disease carrier. Frederick A. Stokes Co., New York, xix + 312 pp.

purpose; nor shall any person aforesaid allow any such bin or pit to be overfilled or to be needlessly uncovered.

"*Sec.* 18*E*. The provisions of paragraphs *C* and *D* shall not apply to the keeping of manure from horses when such manure is kept tightly rammed into the well-covered barrels for the purpose of removal in such barrels.

"*Sec.* 18*F*. No person shall permit any manure to accumulate on premises under his control in such a manner or to such an extent as to give rise to objectionable odors upon any public highway or upon any premises owned or occupied by any person other than the person owning or occupying the premises on which said manure is located. Every person having the use of any manure, in any of the more densely populated parts of the District of Columbia, shall cause all such manure to be removed from the premises at least twice every week between June first and October thirty-first, inclusive of each year, and at least once every week between November first of each year and May thirty-first of the following year, both dates inclusive.

"*Sec.* 18*G*. Every person using within the District of Columbia any building, or any portion of a building, in the city of Washington, or in any of the more densely populated suburbs thereof, as a stable for one or more horses, mules or cows, shall report that fact to the health officer in writing, within thirty days after this regulation takes effect, giving his or her name, and the location of such stable, and the number and kind of the animals stabled therein; and thereafter every person occupying any building, or any portion of a building, in the city of Washington, or in any of the more densely populated suburbs thereof, for the purpose aforesaid, shall report in like manner his or her name and the location of said stable, and the number and kind of animals stabled therein, within five days after the beginning of his or her occupancy of such buildings; provided, that stables recorded at the Health Office as parts of dairy farms in the District of Columbia need not be so reported.

"*Sec.* 18*H*. No person who has removed manure from any bin or pit, or any other place where manure has been accumulated, shall deposit such manure in any place within any of the more densely populated parts of the District of Columbia without a permit from the health officer authorizing him so to do and then only in accordance with the terms of such permit. The provisions of this paragraph shall not apply to the distribution of manure over lawns and parking when such manure has been so thoroughly rotted or decomposed that its distribution gives rise to no offensive odors on adjacent properties or on public thoroughfares."

The stable ordinance in force in Berkeley, California, contains the following sections: —

"*Sec.* 3. Where the premises on which any stable barn, shed or stall is maintained in which any horse, mule or cow is kept, fronts on a street in which is constructed a sewer the following requirements shall be complied with, viz.: The drainage from all single and box stalls where a horse, mule or cow is kept or housed, must in all cases be connected to the street sewer. The floor of all said stalls must be made impervious to water, and the drainage from said stalls must be conducted to the sewer either in tile or cement gutters, of a radius of not less than two inches. The said gutters shall discharge into a 3-inch or 4-inch trap before entering the main sewer. The trap must be protected in all cases by a strainer and be easy of access for cleaning purposes.

"*Sec.* 5. All stables, sheds, barns, stalls, corrals, or stable yards in which any horse, mule or cow is kept shall be thoroughly cleaned out at the following intervals of time: Where stables, barns, sheds, stalls, corrals, or stable yards exist, they shall be cleaned out at least every day. The manure, offal, soiled straw or other refuse matter from all stables, sheds, corrals or stable yards shall be placed immediately upon removal from such stable, barn, shed, stall, corral or stable yard in closely covered metal or metal-lined receptacles, and kept covered until destroyed or removed from the premises. The contents of such receptacles shall be removed therefrom and disposed of at least twice a week."

Another type of stable ordinance requires a permit for the erection and use of stables, etc., and provides for inspection of the same by the score card system. The following is suggested by Mr. Carl L. A. Schmidt, City Bacteriologist of Berkeley:

"*Section* 1. No person, firm or corporation shall own, conduct, operate, manage, or maintain any stable for the use of horses, cows or other animals without first obtaining a permit therefor from the Health Officer in accordance with the conditions in this ordinance hereinafter provided, which permit shall be posted in a conspicuous place in the stable.

"*Section* 2. Any person, firm, or corporation desiring a permit to own, conduct, operate, manage or maintain a stable for the use of horses, cows or other animals shall first make application therefor to the Health Officer, stating the name and residence of the applicant, the exact location of the stable for which he desires a permit and the kind and number of animals to be kept therein.

"*Section* 3. Upon receipt of proper application as provided in Section 2 it shall be the duty of the Health Officer or his authorized representative to visit and inspect the stable for which application has been made, and to report to the Health Officer the sanitary condition of the stable on a score card, the form of which is hereinafter provided, leaving a duplicate copy on the premises inspected.

"*Section* 4. The score card used by the Sanitary Inspector as provided in Section 3 shall be printed in the following form:

CITY OF . . . HEALTH DEPARTMENT

Stable Score Card

Owner or Manager of Stable . . . .
Location . . . .
No. of horses . . . . . No. of cows . . . . No. of other animals . . . .
Board or Private . . . .
Date of Inspection . . . .

	Score Perfect	Score Allowed
1. Character of building		10
If of first class construction of frame or masonry	10	
If poorly constructed	5	
If dilapidated	2	
2. Floors, cement with proper gutters and catch basin and sewer or cesspool connection		10
Cement broken	2	
Cement badly laid	5	
Wood tightly laid	8	
Wood open cracks	0	
3. Manure box, strictly fly-proof		50
Manure box, any part open	5	
Manure box, tight without vent	40	
4. Surroundings perfectly clean		30
If there is water on lot	10	
If there is manure scattered about	3	
If premises are disorderly	5	
		100

If maggots or fly pupæ are found on premises, score will be limited to 49. If doors are not properly cleaned, deduct 5 from total. Filthy catch basin, deduct 5 from total.

"*Section* 5. If, after inspection, the applicant's score shall be over 50, the Health Officer shall issue to the applicant a permit, which shall be numbered consecutively. If the applicant's score be below 50, the Health Officer shall send to the applicant a notice to improve the sanitary condition of his stable so that his score shall be above 50 within a period of 7 days. Failure to do this shall constitute a violation of this ordinance.

"*Section* 6. It shall be the duty of the sanitary inspector to inspect each stable within the City of . . . at least once every three months or oftener at his discretion and to file the score and record of such inspection in the Health Office. Two consecutive inspections of any stable showing a score of less than 50 shall cause the Health Officer to revoke the permit of the stable, and the person, firm or corporation owning, conducting, operating, managing or maintaining such stable shall be guilty of violating this ordinance."

Manure Ordinances. — Inasmuch as 95 per cent of our house flies emanate from horse manure, ordinances regulating the disposal of such material are imperative. Municipal collection and disposal of manure is highly desirable. There is no reason why the city could not require that all manure be collected by authorized scavengers. The manure is then either to be incinerated or properly stored or piled in some designated spot. It is far more preferable that a city have one very large municipal manure pile and know where it is, than to have 500 or more smaller heaps in many out-of-the-way places in all parts of the city. The manure can be adequately treated in the former case and later sold at a price that would assist materially in clearing the cost of municipal collection. The following ordinance constructed by the writer in coöperation with Dr. J. N. Force of the Berkeley (Cal.) Board of Health, is suggested:

ORDINANCE No. . . .

Regulating the Disposal of Manure and Other Refuse Matter from Buildings or Yards where Animals are kept within the City Limits of . . .

Be it ordained by the Council of the City of . . . as follows:

"*Section* 1. The manure, offal, soiled straw or other refuse matter from all buildings or yards where animals are kept shall be collected at least once daily and shall be disposed of by one of the following methods:

(*a*) Said refuse may be stored in ventilated bins or other receptacle of such construction approved by the Board of Health as to prevent the ingress of flies and other vermin, said bin to be emptied at least once a week, or

(*b*) Said refuse may be removed from the premises at least once a day by an authorized scavenger and disposed of in a manner approved by the Health Officer.

(*c*) Said refuse may be spread in a layer not over four (4) inches in depth on the surface of the ground.

"*Section* 2. No manure shall be used for fertilizing purposes within the city limits of . . . which has not been rendered free from live maggots or fly pupæ by treating with saturating quantities of water at a temperature of 195 deg. Fahrenheit, or some other method approved by the Health Officer.

"*Section* 3. The presence of live maggots or fly pupæ in any collection of refuse found in the City of . . . shall be *prima facie* evidence that the provisions of this ordinance have not been complied with.

"*Section* 4. It is hereby made a duty of the Commissioner of Public Health and Safety or any Sanitary Inspector or Police Officer to provide for the inspection of all premises where animals are kept in the City of . . . and examine any manure or other refuse matter to determine the presence of live maggots or fly pupæ.

"*Section* 5. (Penalty clause.)

"*Section* 6. All other ordinances and parts of ordinances in conflict with this ordinance are hereby repealed."

According to Howard (*loc. cit.*) the following regulations concerning manure are in force in the District of Columbia:

"*Section* 3. That manure, accumulated in great quantities; manure, offal, or garbage piled or deposited within 300 feet of any place of worship, or of any dwelling, or unloaded along the line of any railroad, or in any street or public way; cars or flats loaded with manure, or other offensive matter, remaining or standing on any railroad, street or highway in the cities of Washington or Georgetown, or in the more densely populated suburbs of said cities, are hereby declared nuisances injurious to health; and any person who shall pile or deposit manure, offal, garbage, or any offensive or nauseous substance within 300 feet of any inhabited dwelling within the limit of said cities or their said suburbs, and any person who shall unload, discharge or put upon or along the line of any railroad, street or highway, or public place within said cities or their suburbs any manure, garbage, offal, or other offensive or nauseous substances within 300 feet of any inhabited dwelling, or who shall cause or allow cars or flats loaded with or having in or upon them any such substance to remain or stand in or along any railroad, street or highway within the limits of said cities or their suburbs within 300 feet of any inhabited dwelling, and who shall fail, after notice duly served by this board, to remove the same, shall, upon conviction thereof, be fined not less than five nor more than twenty-five dollars for every offense."

Extract from Article IX, Police Regulations:

"*Sec.* 10. No person shall remove or transport any manure over any public highway in any of the more densely populated parts of the District of Columbia except in a tight vehicle, which if not closed must be effectually covered with canvas so secured to the sides of the vehicle as to prevent the manure from being dropped while being removed, and so as to limit as much as practicable the escape of odors from said manure.

"*Sec.* 20. Manures may be deposited in pits below the surface of alleys that are not less than fifteen feet wide, but the pit must not extend more than four feet beyond the building line. The walls must be substantial and water-tight, with stone or iron coping, bedded in cement, set fair with the surface of the alley. They must be covered with heavy wrought-iron doors, flush with the alley pavement or surface, sufficiently strong to carry heavily loaded carts or other vehicles, and provided with ventilation by means of a flue inside of the stable and extending above the roof of the same, and they must be drained by sewer connections, as directed by the Inspector of Plumbing."

Food Ordinances. — Foods must be protected against dust and flies, hence merchants dealing in food products must be required to carry out such measures. But it is manifestly unfair to compel merchants to protect their wares against flies if stable owners who are responsible for the production of the flies are not compelled to do anything to prevent the same.

The Berkeley (Cal.) food ordinance includes the following section:

"*Sec.* 3½. Every manager, owner, or other person keeping, maintaining or being in charge or control of any store, market, stall, shop, bakery, vehicle, or other place where any of the foods or food products mentioned in Section 2 and Section 3 of this ordinance are prepared for sale, stored for sale, offered for sale or sold, or where food which is prepared for immediate consumption is prepared for sale, stored for sale, offered for sale or sold, shall cause such food or food products to be screened in such manner as to prevent flies and other insects from obtaining access to such food or food products, and to prevent handling of the same by patrons or prospective purchasers.

Howard (*loc. cit.*) cites the following regulation for the District of Columbia relating to food:

"Every manager of a store, market, dairy, café, lunch room, or any other place in the District of Columbia, where food, or a beverage, or confectionery, or any similar article, is manufactured or prepared for sale, stored for sale, offered for sale, or sold, shall cause it to be screened effectually, or effectually protected by power-driven fan or fans, so as to prevent flies and other insects from obtaining access to such food, beverage, confectionery or other article free from flies and other insects at all times. Any person violating the provisions of this regulation shall, upon conviction thereof, be punished by a fine of not more than twenty-five dollars for each and every offence. This regulation shall take effect from and after the expiration of thirty days immediately following the date of its promulgation."

CHAPTER XV

BLOOD-SUCKING MUSCIDS

(Tsetse Flies, Stable Flies, Horn Flies)

A. Tsetse Flies

Family Muscidæ, Genus Glossina

Habits. — The tsetse flies are commonly regarded as the world's most dangerous insects, and this with much reason, for the African sleeping sickness, one of the most dreaded diseases, is transmitted by these flies. Fortunately, however, the tsetse flies are found solely in Africa and there only in certain restricted areas.

Fig. 135. — *Glossina palpalis* (tsetse fly), carrier of African sleeping sickness. × 3.6.

The tsetses are typical intermittent blood-sucking insects; in this habit both sexes partake, and it is said that they bite not only during the day, but also at night when the moon is bright. Their flight is very rapid and direct. They occur most abundantly along heavily wooded watercourses, where big game animals abound, especially the African buffalo, antelope, etc. Still other species occur most commonly in less thickly wooded dry localities.

Structural Characteristics. — The tsetse flies[1] belong to the genus

[1] The writer has gathered data for this chapter by an examination of the tsetse fly collections and exhibits in the Liverpool School of Tropical Medicine, the British Museum and the International Hygiene Exhibit held in Dresden in 1911.

Glossina, which includes medium-sized to large flies, — from the size of a house fly to that of a blow fly. They are brownish black in color, the body is distinctly wasplike, *i.e.* with constricted waist (Fig. 135). The wings when at rest are closed scissors-like (not unlike the Texas screw worm fly) and project beyond the abdomen. The wing venation (Fig. 136) is characteristic "especially in the course of the fourth longitudinal vein. The anterior transverse vein is very oblique. The bend in the course of the fourth vein, before it meets the anterior transverse vein, is absolutely diagnostic" (Stephens and Christophers). The palpi are more than half as long as the proboscis, which points bayonet-like in front of the head. The antennal arista is plumose only on the upper side (Fig. 137). The mouth parts consist of the labium which ensheaths the two piercing setæ, — the dorsally located labrum and the inner hypopharynx, as in Stomoxys. The characteristic "onion shaped" bulb is conspicuously located at the base of the proboscis (Fig. 138).

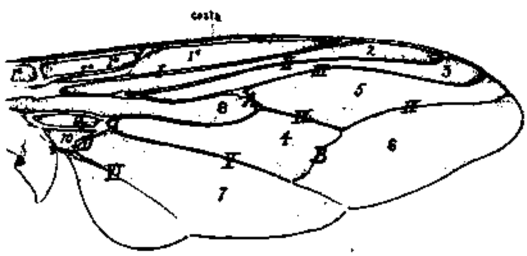

FIG. 136. — Wing of a Glossina fly. I^a, auxiliary vein; I to VI = first to sixth longitudinal veins; *A*, anterior transverse vein; *B*, posterior transverse vein; *C*, anterior basal transverse vein; *D*, posterior basal transverse vein; 1^a, 1^b, 1^c, first, second and third costal cells; 2, marginal cell; 3, submarginal cell; 4, diskal cell; 5, 6, 7, first, second and third posterior cells; 8, anterior basal cell; 9, posterior basal cell; 10, anal cell. (Nomenclature after Austen.) × 8.

Life History. — The tsetse flies are viviparous, depositing well-advanced larvæ; indeed, these are fully grown and pupate within a few hours after extrusion. The flies are said to have a striking dislike for excrementous matter, and the larvæ are ordinarily deposited in the root tangles of the banana, mangroves and other tropical vegetation. The time required for the pupal stage is from six to eight weeks.

The pupæ (Fig. 139) have striking posterior protuberances of the terminal segments. These are so situated as to produce an inclosure for the larval stigmata.

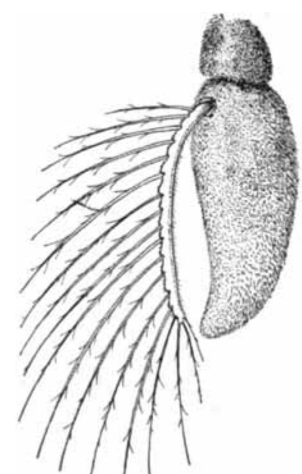

FIG. 137. — Antenna of a Glossina fly, showing arista with branched hairs. (Much enlarged.)

Trypanosomiasis. — The tsetse, or Glossina, flies are most important carriers of the Trypanosoma of warm-blooded animals. The term *Trypanosomiasis* applies to all diseases produced by flagellate Protozoan parasites of the genus Trypanosoma, and includes such diseases as African sleeping sickness, nagana, surra, etc. The trypanosomes belong to the Class Zoömastigophora and to the order Trypanosomatida, are miscroscopic, elongate, more or less spindle-shaped, blood, lymph or cerebrospinal fluid inhabiting parasites, found in many species of vertebrate animals, from fish to man, and apparently not all species are pathogenic. At or near the middle of these spindle-shaped organisms lies an oval or round body, the *nucleus;* anterior to this is usually the rather long filamentous appendage, the *flagellum,* which can be traced back along the border of a flaplike structure, or *undulating membrane,* to a body considerably smaller than the nucleus, lying in the posterior end, the *blepharoplast* (Fig. 1*b*). Immediately adjacent to the blepharoplast there is often a vacuole, and distributed throughout the body of the trypanosome are distinct chromatin bodies or points.

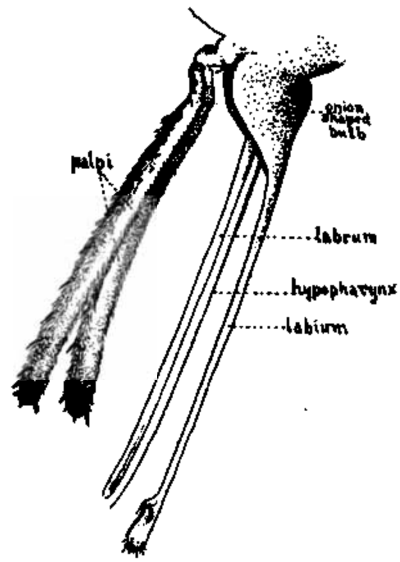

Fig. 138. — Mouth parts of a Glossina fly. × 17.

The Trypanosoma increase in the vertebrate host by longitudinal division. Both the nucleus and the blepharoplast divide, and the flagellum splits into two, or in some species a new flagellum originates from

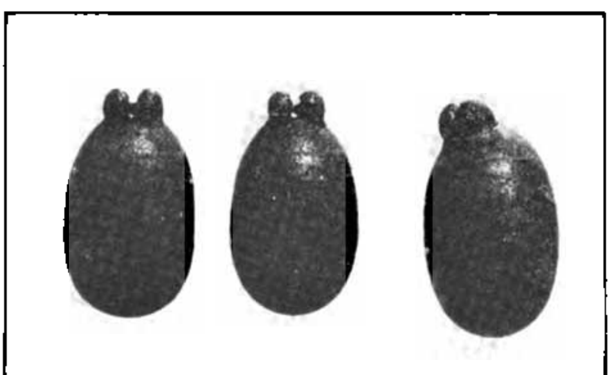

Fig. 139. — Pupæ of the Glossina fly. × 4.8.

the new blepharoplast. Thus, in the latter case, the flagellum is first located posteriorly and migrates anteriorly as the organism grows older. In *Trypanosoma lewisi* there may be found a rosette. The developmental stages which are undergone in the intermediary hosts are not well known, but there is certainly a series of changes undergone within the insect host.

There are also described male forms said to be "excessively slender, staining deep blue, with a sharply defined, rather long, chromatin-rich nucleus; more actively motile than other forms; 'also female forms' with short flagellum membrane, little folded, two or three times as broad as other forms; staining a light blue; have few or no granules, and the nucleus is spherical" (Stephens and Christophers). Besides these there are also described indifferent forms, "the most numerous form, nucleus not sharply defined and the protoplasm containing numerous granules;" also encysted forms, latent forms and involution forms.

The first trypanosome was discovered by Valentin in 1841 in the blood of the salmon. The name *Trypanosoma*[1] was given to these organisms by Gruby in 1842–43. The attention was not called to trypanosomes of mammals until the work of Lewis in 1878, on the parasites of the blood of the rat in India. After that followed the dicovery of other important *pathogenic* trypanosomes, *e.g.* in 1880 Evans discovered the trypanosome causing surra in horses; in 1897 Bruce found the trypanosome of nagana, known as the tsetse fly disease. In 1901 Dutton found trypanosomes in human blood, and in 1903 Castellani found them in the cerebrospinal fluid of negroes in Uganda suffering from sleeping sickness. The trypanosomes found by Castellani were supposed to be a different species from that of Dutton (*Trypanosoma gambiense*) and were called *T. ugandense* Castellani, 1903. Kruse later gave to this trypanosome the name *T. castellanii* Kruse. The important discoveries of Dutton and Castellani were confirmed by D. Bruce, who found these trypanosomes 38 times out of 38 in the cerebrospinal fluid obtained by a lumbar puncture in natives of Uganda suffering from sleeping sickness, and twelve times out of thirteen in the blood. According to the rules of priority applied to nomenclature, the last two specific names must give way to *Trypanosoma gambiense* Dutton, the older term.

African Sleeping Sickness. — The most important tsetse fly disease is African sleeping sickness, the causative organism of which is *Trypanosoma gambiense* (Fig. 1*b*). This disease is endemic in certain regions of Africa, particularly the French Congo and the Congo Free State, where for several years it has increased in territory and has caused great ravages. It has been estimated that between 1896 and 1906 from 400,000 to 500,000 natives perished from this pestilence. Dutton and Todd found that in some villages from 30 per cent to 50 per cent of the population was infected.

Age does not affect the distribution of the malady, since children, as young as eighteen months to two years, have been known to be infected. Sex does not influence the disease. Occupation and social

[1] Laveran, A., et Mesnil, 1904. Trypanosomes et Trypanosomiasis. Paris, xi + 417 pp.

position, however, do show a marked influence. The great majority of the cases observed are among the agricultural and lower classes.

The seasons seem not to influence the advance of the disease, but because of the long period of incubation or of latency which precedes the usual appearance of nervous symptoms, the influence of the seasons is hard to determine.

There are two distinct phases in sleeping sickness. During the first phase the trypanosomes are in the blood (Fig. 140), usually in small numbers. With the negroes there are said to be no morbid symptoms, but with the whites it is manifested by an irregular fever. Glandular enlargement is an early and constant feature, and the trypanosomes are practically always found in the enlarged glands. In the second place, the trypanosomes are constantly found in the cerebrospinal fluid; there is nervousness and trembling until drowsiness appears, the fever taking on the hectic character. Drowsiness gives way to lethargy, and finally the victim falls into a comatose state.

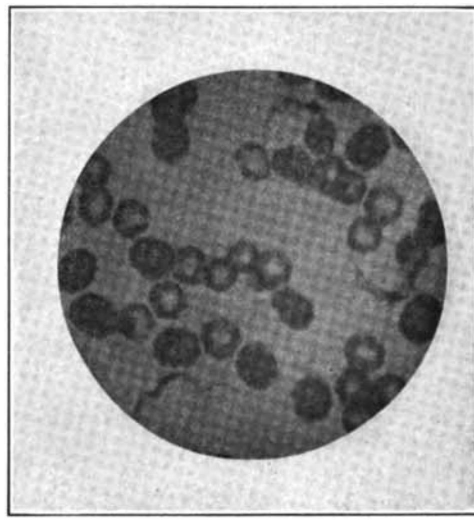

FIG. 140. — Photomicrograph of a blood smear, showing *Trypanosoma gambiense* of African sleeping sickness. × 625.

The first stage may last several years, while the second is from four to eight months' duration, exceptionably one year.

The description of the trypanosome is given by Stephens and Christophers, viz.: "12–28 by 1.5–3 micra. The blepharoplast is oval. There is not uncommonly a vacuole in close association with it. The trypanosome, at least in animals, occurs in two main forms, a long and a short." *Glossina palpalis*, a tsetse fly, and its varieties, is unquestionably the principal, if not the sole, agent of transmission. After inoculation into the human the incubation period varies, it is said, from several months to several years.

A second species of trypanosome producing African sleeping sickness in Rhodesia, Nyasaland and adjoining territory is *T. rhodesiense* (Stephens and Fantham).[1] In this trypanosome the nucleus is usually in the blepharoplast end of the parasite. The carrier is *Glossina morsitans*.

[1] Stephens, J. W. W., and Fantham, H. B., 1913. Trypanosoma rhodesiense (Stephens and Fantham), a second species of African trypanosome producing Sleeping Sickness in man. Trans. Fifteenth Internat. Cong. Hyg. and Dem., Vol. 5, Pt. II, pp. 615–619.

Transmission. — The natives of French Guinea long attributed the power of disseminating sleeping sickness to flies and it had already been shown that nagana, a disease of horses and dogs, was transmitted by tsetse flies when Dutton and Todd studied the biting flies of Gambiense. These investigators found that of the flies which bite man and animals, *Tabanus dorsovittata* and *Glossina palpalis* were the most important, the latter being very common in western Africa, where it abounds in the mangroves which line the rivers and water banks during the warmer months when these insects are very troublesome. Experiments, however, made by these workers gave negative results. It was Bruce and his collaborators who subsequently went over the matter and showed that *Glossina palpalis* is the principal agent of transmission. Other tsetse flies known to transmit sleeping sickness are *Gl. palpalis* var. *wellmani*, *Gl. fusca*, also *Gl. morsitans*.

Animal experimentation indicates that these flies can transmit the causative protozoon mechanically for a period of less than forty-eight hours, though the organisms become more and more attenuated after the fly has bitten the diseased individual and loses its power of infection in less than forty-eight hours. Thus the tsetse fly proves itself a mechanical carrier for only a few hours during which time its soiled proboscis is involved, *i.e.* trypanosomes are injected into the wound produced by the bite before the proboscis is cleaned.

It is, however, well known that trypanosomes taken into the stomach of the fly pass through a metamorphosis, developing into two forms known as male and female. These latter give way to an indifferent type and in from four to five days all trypanosomes disappear. Recent experimental evidence indicates that the flies become infective once more at the end of about four weeks, and then appear in the salivary glands of the insects. Nuttall[1] states that the trypanosomes appear in the salivary glands of the fly after a period of twenty-five to twenty-eight days following the infective meal. During this interval, except as noted above, the flies are incapable of producing infection. The parasites in the salivary glands of the fly resemble *T. gambiense* as seen in the mammalian blood and they persist as long as the fly lives. The Sleeping Sickness Commission has found that infectivity lasts at least ninety-six days. The life of a female *Gl. palpalis* in captivity has been observed to be about four and one half months. The same author (Nuttall) states that injections of *either* the *gut content* or *salivary gland emulsion* produce infection after about the twenty-fifth day. Under laboratory conditions only about 5 per cent or 6 per cent of the flies become infective.

The Question of Reservoirs. — Inasmuch as infective flies have been taken in regions uninhabited by man for at least three years, there must be some other animal or animals in which the trypanosome of

[1] Nuttall, G. H. F. The Herter Lectures: II, Trypanosomiasis, Parasitology, Vol. V, No. 4, pp. 275–288.

sleeping sickness is preserved in an infective state. This seems further more imperative since no evidence is at hand that the trypanosomes are transmitted from the parent fly to the offspring, *i.e.* hereditarily. There is now sufficient evidence at hand to prove that the African antelope serves as a perfect reservoir for the trypanosome,[1] that these animals recover from the experimental infection and therefore serve as " chronic carriers." Many animals may serve as reservoirs. (See Nuttall, 1913, *loc. cit.*)

Nagana. — As sleeping sickness is to man so is nagana to domesticated animals, especially horses and dogs. *Trypanosoma brucei* Plimm and Bradf. is the causative organism of nagana, which malady was early known as the fatal tsetse fly disease of African horses and mules, less fatal in cattle and sheep. The disease is characterized by progressive emaciation, fever, œdema of the abdomen and genitalia and marked depression. The trypanosomes are found in the blood and especially the lymph gland swellings from the beginning of the first symptoms.

The trypanosome is described by Stephens and Christophers, viz.: " 26–27 micra in rats, 28–33 micra in horses. The nucleus lies almost in the middle. The blepharoplast is almost quite round. The flagellum is generally separated from it by a slight interspace."

For some years nagana was known as *the* tsetse fly disease. *Glossina morsitans* and *Gl. longipalpus* relate to its transmission in practically the same way as does *Glossina palpalis* to sleeping sickness, *i.e.* the fly is infective for three or four days after feeding on an infected animal, then becomes non-infective for a period of about three weeks and then again becomes infective, remaining so for the rest of its life. The incubation period after inoculation into the body of the host is said to be about ten days.

Control of the Tsetse Fly Disease. — Thus far little progress has been made in the treatment or immunology of tsetse fly diseases; upon the latter no doubt rests the ultimate solution of the problem. A ready means for the destruction of the flies is unknown. Although numerous flies may be destroyed by catching them with sticky substances such as birdlime, their reduction is hardly if at all noticeable. Repellents, though many have been tried, give poor results; oil of citronella seems to be of some value. The general and practical control of breeding places offers unsurmountable difficulties owing to the fact that the larvæ are retained within the body of the female, hence are not directly dependent upon an external supply of food. Starving the adult flies by eliminating wild animals upon which they are dependent for blood is a method employed experimentally in many localities. The wide range of food animals, the question of reservoirs and the need of domesticated animals reduces this method to one of secondary importance to be employed in association with other methods.

A study of the habits of the tsetse shows that villages located in

[1] See Proc. Roy. Soc., Series B, vol. 83, pp. 513–527, 1911.

the midst of extensive clearings and not too near water courses are largely free from these insects. The clearings should be from 400 to 600 yards in width and can best be maintained by placing them under cultivation (rice and larger shade-producing vegetation excepted). Wells should be utilized for water supply.

Screening is an important adjunct to the control of sleeping sickness. Dwellings, trains, steamers and other conveyances should be carefully screened.

The use of veils, gloves and loose white garments is highly recommended.

Since the tsetse fly diseases spread along trade routes and extend from infected centers, there is an obvious demand for the control of transportation to prevent as far as possible the employ of infected individuals.

Owing to the complicated colonial situation in Africa, both geographically and commercially, the control of trypanosomiasis calls for hearty coöperation among the powers concerned.

Systematic. — All flies belonging to the genus Glossina partake of the following characteristics: medium-sized flies from size of house fly to blowfly, dark brownish in color; wings when at rest folded scissors-like over the back, longer than the abdomen; fourth longitudinal vein bends sharply before meeting the anterior transverse vein; proboscis when at rest projecting horizontally in front of the head; the base of proboscis is provided with an onion-shaped bulbous expansion; the arista is plumed on upper side.

The following species[1] may be mentioned:

(1) *Glossina palpalis* Robineau-Desvoidy is a medium-sized tsetse fly from 8 to 9 mm. in length. Its general color is light brown with a dusting of gray. The antennæ are dusky, the arista has 18 aristal hairs. The thorax heavily dusted with gray and has dark lines and spots. The abdomen is light brown beneath dusted with gray; above it is nearly black with a longitudinal, median narrow light brown stripe. The halteres are white. The legs are light brown with indistinct dark spots on the tarsi. The hind tarsi are black.

This species is found throughout West Africa from the Congo to the Senegal, wherever there is water.

Glossina palpalis var. *wellmani* Austin varies from the above in that it has a yellowish brown frontal stripe, and tarsi nearly white. It occurs in Angola.

Glossina morsitans Westw. is said to be almost identical with *Glossina longipalpus*, except that it is ordinarily somewhat smaller. Grünberg[1] declares that it would be more correct to consider *morsitans* as a variety of *longipalpus*. Furthermore, because of the fact that both species are

[1] Grünberg, Karl, 1907. Die Blutsaugenden Dipteren. Verlag von Gustav Fischer in Jena. vi + 188 pp., 127 figures. (The above descriptions of tsetse flies are adapted after this author.)

transmitters of nagana, the separation of the two species has no practical value.

The distribution of this species coincides with that of *Gl. longipalpus*, though it is ordinarily attributed to a much greater portion of Africa, because its habitat consists of less heavily wooded and drier areas.

Glossina longipalpus Wiedem. is also a medium-sized fly ranging from 8–10 mm. in length. The color is light brown with very little gray. The antennæ are dark brown, the arista is light brown with 25 aristal hairs. The palpi are light brown, tipped with black. The thorax is heavily dusted with gray. The abdomen is light brown, marked dorsally, to the right and left, on the 2–6 segments with black semilunar lateral spots, resting broadly on the proximal end of each segment. The halteres are white. The legs are light brown with black tipped pro- and meso-thoracic tarsi; the hind legs are black.

This species occurs in Sierra Leone and British Central Africa.

Other species of Glossina flies are the following: *Gl. pallicera* with 20–22 aristal hairs (Grünberg); *Gl. pallidipes* with 25 aristal hairs (Grünberg); *Gl. longipennis* with 18–20 aristal hairs (Grünberg); and *Gl. fusca*, a large species (11–13 mm.) also with 18–20 aristal hairs (Grünberg).

B. Stomoxys or Stable Flies

Family Muscidæ, Genus Stomoxys

General Characteristics. — Owing to similarity in color and size (Fig. 141) the *Stomoxys* fly is often mistaken for the common house fly,

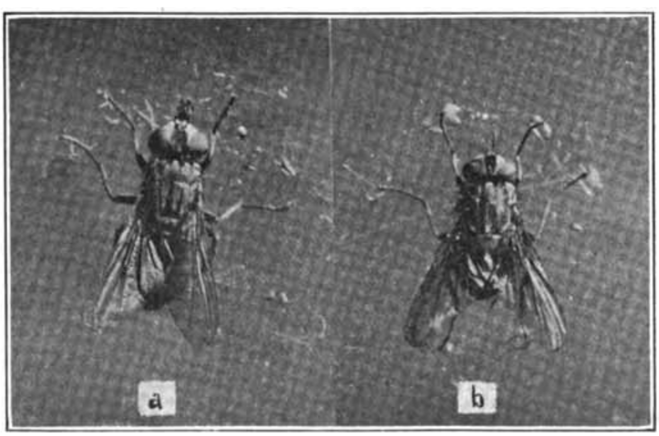

Fig. 141. — (*a*) The common house fly (*Musca domestica*); (*b*) the stable fly (*Stomoxys calcitrans*). × 2.5.

Musca domestica. However, the former is more robust with broader abdomen. In color it is brownish gray with a greenish yellow sheen; the outer of the four longitudinal thoracic stripes are broken and the abdomen is more or less checkered. The wings when at rest are widely spread apart at the tips, are distinctly iridescent and the apical cell is open. When resting the fly has its head thrown well up and the wings slope decidedly toward the surface upon which it has settled. The proboscis protrudes bayonet-like in front of the head. The antennal arista, unlike the house fly, bear setæ on the upper side only (Fig. 29).

Habits. — Although the Stomoxys fly is commonly called the stable fly, it occurs much less abundantly (often absent) about stables than does the house fly. "Biting house fly" is a term often applied, since the fly commonly occurs indoors especially in the autumn and during rainy weather. The Stomoxys fly is typically an out-of-door fly and is usually to be found in summer where domesticated animals occur, especially cattle. Its occurrence around stables is traceable to the presence of cattle or horses usually, and not to the presence of manures directly. Sunny fences, walls, light-colored canvas coverings and light objects in general when in the proximity of cattle are abundantly frequented by Stomoxys flies.

The Stomoxys fly is a vicious "biter," draws blood quickly and fills up to full capacity in from 3 to 4 minutes if undisturbed, but ordinarily even when undisturbed changes position frequently or flies to another animal, where the meal is continued. This fly feeds readily on many species of warm-blooded animals, for example, rats, guinea pigs, rabbits, monkeys, cattle, horses and man. Both sexes are blood-sucking. The flight of the Stomoxys fly is direct and swift.

Light Reactions. — The Stomoxys flies respond positively and strongly to light, being much more responsive to this stimulus than house flies, hence the former are normally out-of-door flies, while the latter are house flies, responding readily to odors emanating from the house. Because of the strong positive reaction to light these flies can easily be transferred from breeding jars to other receptacles by covering the former with black cloth, leaving an opening toward the light into which opening a test tube is inserted. Hundreds of flies can thus easily be transferred in a few minutes. Observations on the photic reactions of these flies bid fair to give very interesting results.

The larvæ, like those of flesh flies and house flies, are decidedly negative to light. In breeding these flies, the larvæ must be supplied with sufficient material so that they can bury themselves deeply, — they are thus protected against light, and enough moisture must be applied to keep the mass of material in a "soggy" condition. Too much moisture is, however, destructive.

Breeding Habits and Life History. — Although the Stomoxys fly can successfully be reared in the manures of horses, cattle, sheep, etc., it may be safely said that it does not breed commonly in excrement under field conditions unless straw or hay predominates. For every thousand house flies bred in horse manure, there are, as a rule, not more than one or two Stomoxys flies. The very best breeding places are afforded by the left-over hay, alfalfa or grain, in the bottoms or underneath out-of-door feed troughs in connection with dairies (Fig. 142). This material

FIG. 142. — A feed trough for dairy cattle which furnishes an ideal breeding place for Stomoxys flies. The moist lower layers of material in the trough furnish abundant food for the larvæ.

soon becomes soggy and ferments, and here practically pure cultures of Stomoxys larvæ may be procured. The material must be moist; dry-

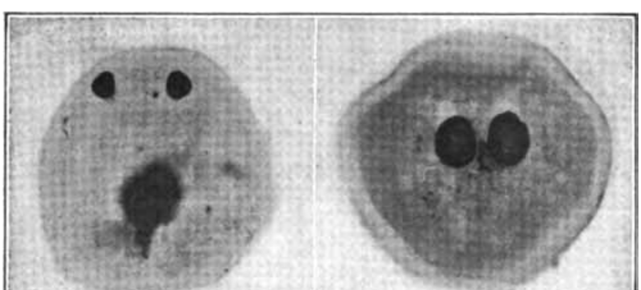

FIG. 143. — Showing posterior larval spiracles of *Stomoxys calcitrans* (left); *Musca domestica* (right). × 21.

ness prevents development. Piles of wet fermenting weeds and lawn cuttings also furnish fairly good breeding material. Piles of decaying onions have been found by the writer to harbor myriads of larvæ late in autumn.

The larvæ of Stomoxys and of the house fly can readily be differentiated by the form, size and position of the posterior spiracles (Fig. 143), otherwise they resemble each other closely. The pair of posterior spiracles of the Stomoxys larva are roughly triangular, widely separated and situated near the periphery, while in the house fly larva they are elliptical, quite large, close together and more central in position.

The eggs of the Stomoxys fly are about 1 mm. long, curved on one side, straight and grooved on the opposite side. In depositing her eggs the female fly often crawls far into the loose material, depositing her eggs usually in little pockets in small numbers, often in pairs. Egg depositions range in number from 23 to 102, usually between 25 and 50, and there are ordinarily four or five layings. Mitzmain[1] has found in his observations made in the Philippine Islands that the maximum number of eggs produced by a single *Stomoxys* is 632 and possibly 820, and that there may be as many as twenty depositions during the lifetime of the female.

The incubation period varies from two to five days, commonly three days, at a temperature of 26° C. Higher temperatures result in a shorter incubation period. The newly hatched larvæ bury themselves in their food at once, thus protecting themselves against light and dryness. At a temperature of from 21° to 26° C. the larvæ reach full growth in from fourteen to twenty-six days. Mitzmain (*loc. cit.*) found that the larval stage averaged twelve days at a room temperature of 30° to 31° C.

Before pupation the larvæ usually crawl into the drier layers of the breeding material, where the chestnut-colored pupæ are often found in enormous numbers. The pupæ are from 6 to 7 mm. long and may be recognized by the posterior spiracles as in the larva. The pupal period again varies, dependent on temperature especially. At a temperature of from 21° to 26° C. this period varies from six to twenty-six days, with the greatest frequency between nine days and thirteen days (Table XII).

TABLE XII

TABLE SHOWING DAY OF EMERGENCE OF STOMOXYS CALCITRANS AFTER DAY OF PUPATION. LARVÆ PUPATING IN AN INSECTARY AT A TEMPERATURE OF FROM 21° TO 26° C.

	Pupal Period in Days	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Totals
A	No. flies	1	2	42	108	424	167	85	15	8	4	2	0					858
B	No. flies	3	10	12	80	200	70	20	16	10	19	4	3	0				427
C	No. flies	20	125	85	100	200	70	120	50	75	30	20	30	40	15	4	0	887

[1] Mitzmain, M. B., 1913. The bionomics of *Stomoxys calcitrans* Linnæus; a preliminary account. The Philippine Journal of Science, Vol. VIII, No. 1, Sec. B., pp. 29–48.

At an average temperature of 29° C. Mitzmain (*loc. cit.*) found the pupal period to average five days.

If not handicapped, the imago emerges with astonishing rapidity, crawls away, unfolds its wings and is ready to fly away in less than half an hour. The fact that the proboscis is temporarily attached beneath the thorax gives the newly emerged insect a very peculiar appearance, and it may then be easily mistaken for a house fly.

Summarizing the life history of the Stomoxys fly (Fig. 144) it may be said that at a temperature of 21° to 26° the *shortest* periods are: egg, two days, larva, fourteen days, pupa, six days, total twenty-two days; the *average*, egg, three days, larva, fifteen days, pupa, ten days, total, twenty-eight days; the *maximum*, egg, five days, larva, twenty-six days, pupa, twenty-six days, total, fifty-seven days. The total time at 21°

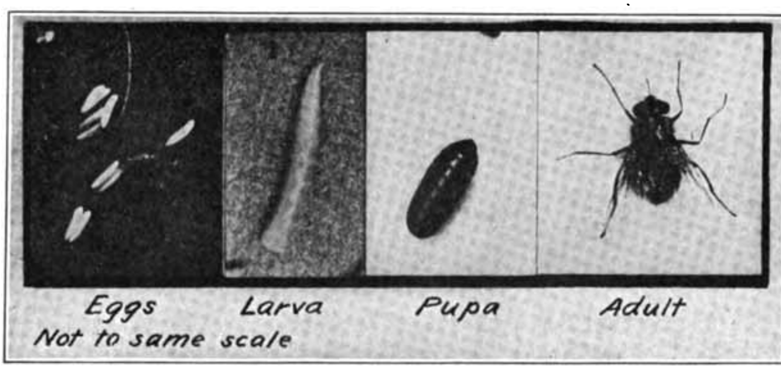

FIG. 144. — Showing the life history of the stable fly or stomoxys fly (*Stomoxys calcitrans*). (Photo by H. F. Gray.) × 2.

from the laying of the egg to the emergence of the imagines was from thirty-three days to thirty-six days as observed in five individual cases. Mitzmain (*loc. cit.*) reports the development of this fly in twelve days under optimum conditions.

Copulation takes place within a week and egg deposition begins in about eighteen days after emergence from the pupa cases at a temperature of from 21° to 26° C. Higher temperatures undoubtedly decrease this time.

Longevity. — With approximately 4000 flies under continuous daily observation in glass quart jars, 50 flies to a set, the writer has found that the average length of life of the Stomoxys fly under favorable conditions of feeding (*i.e.* daily feedings on monkeys or rabbits) is about twenty days. The maximum life under these conditions was found to be sixty-nine days and several hours, — observed in a female (Fig. 145).

Mitzmain (*loc. cit.*) has found the maximum for a female fly to be seventy-two days and for the male ninety-four days.

The writer has observed that a set of flies which fed only on sugar water deposited no eggs, although many of them lived twenty days or

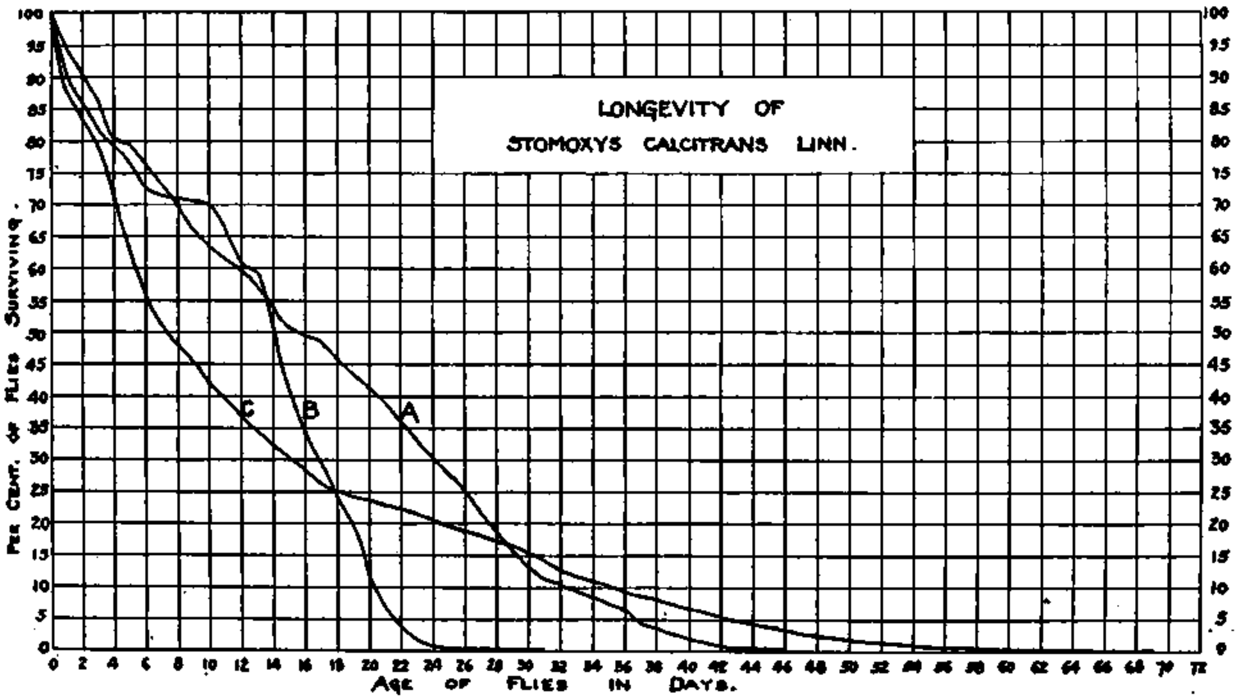

FIG. 145. — *Longevity chart of Stomoxys calcitrans:* *A*, percentage curve of 1,300 stable flies surviving on each day after hatching; hatched between Dec. 12 and 20, 1912; used in Experiment 1; room temperature, usually between 12° and 20° C. (53.6° and 68° F.). *B*, percentage curve of 650 stable flies surviving on each day after hatching; hatched between Dec. 22, 1912, and Jan. 3, 1913; used in Experiment 3; insectary temperature, from 23° to 36° C. (from 73.4° to 78.8° F.). *C*, percentage curve of 2,000 stable flies surviving on each day after hatching; hatched between April 7 and 18, 1913; used in Experiments 5, 6 and 7; room temperature, usually between 12° and 20° C.

longer, while control flies fed on blood did lay eggs. Hence it seems apparent that the flies must have blood in order to develop eggs.

As a Cattle Pest. — In a most useful and interesting paper on the stable fly, as a live stock pest, Bishopp[1] regards this fly as very important. Injury is brought about in various ways, *e.g.* worry, due to the attacks of myriads of flies; loss of blood; lessening of the milk supply from 40 to 60 per cent; loss of flesh; bringing on attacks of acute Texas fever if the cattle are already parasitized; etc.

Surra. — Surra is one of the most important diseases of horses in the Philippine Islands, and its spread on these islands behooves the government to a most careful consideration of its transmission. The causative organism is *Trypanosoma evansi* (see Chapter XII) which is harbored by a number of hosts, mainly horses, in which the disease is highly fatal, also mules and the carabao, and experimentally in monkeys, guinea pigs and rabbits.

The Stomoxys fly has been regarded by some authors as an important carrier of this trypanosome. Unfortunately there is little or no conclusive experimental evidence in favor of this theory. Mitzmain[2] in a most important contribution on this subject presents very good evidence that this fly need not be regarded as a factor in the transmission of surra, that its spread is attributable mainly to a horsefly, *Tabanus striatus*, the common horsefly of the Philippine Islands. In a letter to the writer Mitzmain states that *Stomoxys calcitrans* was used daily on clean animals up to ninety-four days after removal from the infected hosts without successful transmission.

Poliomyelitis. — Poliomyelitis, also known as infantile paralysis, was first described in 1820 in Norway, and it seems quite likely that the spread of this disease is traceable to immigrants from the Scandinavian peninsula. Severe epidemics of this disease are apparently not recorded until recent years, the latter few years of the last century and the beginning of this.

Apparently the first epidemic to be reported in the United States was in 1894 in Vermont, and a year later a small epidemic was reported in California. During the past five years the disease has been spreading to an alarming extent. In 1907 over 2500 cases occurred in New York State, in 1909 nearly 1000 cases in Massachusetts and over 600 cases in Nebraska; in California for the year beginning November 1, 1911, and ending October 31, 1912, there were 495 cases with a mortality of 23.3 per cent. Children between the ages of three and four seem to be most susceptible to the disease and the mortality is highest between these ages. The disease is, however, not restricted to infants, since adults are known to show characteristic symptoms.

The symptoms of the disease in the first stage are vague, — there is

[1] Bishopp, F. C., 1913. The stable fly (*Stomoxys calcitrans* L.), an important live stock pest. Journ. Econ. Ento., Vol. 6, No. 1, pp. 112–127.

[2] Mitzmain, M. B., 1913 (*loc. cit.*).

fever, nervousness, gastric and intestinal disturbances, loss of appetite and headache; these symptoms are followed by the more definite conditions of paralysis of arms and legs, usually asymmetrical, trembling and finally complete paralysis. Death often occurs through paralysis of the diaphragmatic muscles. If recovery takes place, often months elapse before complete use of arms and legs is regained.

The causative organism is unknown, but is filterable and hence belongs to that already large group of ultra-microscopic organisms, including those of yellow fever and dengue. The incubation period in the human has not been ascertained, but in monkeys it is as short as three or four days and in these animals death often ensues in five days.

The epidemiology of Poliomyelitis is complicated. The virus is known to retain its virulence under most adverse conditions, said to remain virulent in dust (Neustaedter and Thro).[1] The disease can be produced by painting the nasal mucosa with the virus. All this would seem to point toward ease of transmission and infection, which is really not the case, otherwise epidemics of this disease in schools would be common occurrences. Again, healthy monkeys caged with monkeys infected with the disease do not readily become infected by contact. Notwithstanding these facts cases are cited in which the disease has been transmitted by contact. On the other hand cases are numerous in which the patients are far separated from other cases.

Because of this peculiar distribution the attention of investigators has been called to the possibility of insect transmission. The following quotation is taken from the California State Board of Health Special Bulletin on Poliomyelitis (October 15, 1912).

"In 1909, Dr. J. H. Hill, Epidemiologist of the Minnesota State Board of Health, presented the apparent relation of dusts to the occurrence of the disease and its frequent appearance on premises having accommodations for horses and other animals.

"Professor W. B. Herms, of the University of California, has for several years considered the "biting fly" (*Stomoxys calcitrans*) to be a possible factor in transmitting the disease.

"Dr. M. W. Richardson, Secretary Massachusetts State Board of Health, in 1911 was one of the first workers to begin the systematic collection of insects found on the premises of poliomyelitis cases. His observations and his strong suspicion of the "biting fly" based upon finding this species of fly as the only insect constantly present in the majority of houses where poliomyelitis had occurred, were presented to the American Public Health Association in Havana in December, 1911.

"Dr. Flexner of the Rockefeller Institute for Medical Research and his associates, in their several progress reports on Poliomyelitis have pointed out the possibility of insects being a factor in disseminating the disease, and have emphasized the fact that if this could be proved it would explain many of the difficult points in its epidemiology.

"Doctor Frost of the United States Public Health Service has been constantly observing the epidemiological factors in American outbreaks of poliomy-

[1] Neustaedter, M., and Thro, W. C., N. Y. Med. Journ., 1911, XCIV, p. 813.

elitis during the past three years, in an effort to collect evidence supporting or disproving the efficiency of administrative measures that have hitherto prevailed.

"In the summer of 1912, Dr. Richardson continued his work and Dr. M. J. Rosenau of Harvard University began a series of scientific experiments to demonstrate if possible, whether poliomyelitis can be transferred from infected monkeys to well monkeys through the agency of the "biting fly" (*Stomoxys calcitrans*). In a preliminary scientific announcement, September 26, 1912, before the International Hygienic Congress, Dr. Rosenau stated that he had succeeded in accomplishing this in his first series of experiments."

The following is quoted from a report of Rosenau's work in the Journal of the American Medical Association (Vol. LIX, No. 14, p. 1314) under "Proceedings of the International Congress on Hygiene and Demography."

"In reference to the transmission of poliomyelitis by the biting fly, we were led to focus our attention on this biting fly (*Stomoxys calcitrans*) as an intermediate host in the transmission of a particular infection referred to by Dr. Richardson. When I first began to study the disease, I regarded it probably as one which is spread by direct contagion, by contact, either directly or indirectly, from person to person. The first circumstance which shook my faith that we were dealing with a contagious disease was the fact that we had eighteen negative results in attempting to prove the presence of the virus in the secretions from the nose and throat. I could not help asking at the time if it were not possible to find the virus, which is so potent, in the secretions of the nose and throat of persons who have the disease and those who are convalescing from the disease. These results were confirmed at the same time by Strauss, of New York, who had negative results in a large series and by Neustaedter's recent results and by other results, all of the examinations having proven negative excepting one recently reported by Kline, Patterson and his associates at this congress and in the literature recently.

"A second circumstance which led me to believe we were not dealing with a contagious disease was the fact brought out by Dr. Richardson. Children in all stages of this disease were crowded into schools, institutions, tenement districts and other places where there was every chance for the spread of the disease, but it did not spread there, but it continued to spread in the rural, thinly scattered districts where one would not expect to find contagious disease. There was a resemblance to rabies. All those who have worked with this virus in laboratories were at once struck with the resemblance between poliomyelitis and rabies. The latter being a wound infection, there is some analogy between it and poliomyelitis, and poliomyelitis might be transmitted through some sort of wound. I was fortunate enough to have had experience with yellow fever, both in the investigation of it and the sanitary measures against it, before the mosquito period, and I was much struck with many analogies which came to me between that disease and certain features of poliomyelitis.

"The work I bring to your attention consisted of taking a number of flies, — *Stomoxys calcitrans*, — caught in a net and bred for the purpose; you can catch several hundred of these flies in a stable in a very short time. We placed these flies in a large cage and exposed monkeys to their bites, the monkeys having been purposely infected with the virus of poliomyelitis. Care was taken to place the monkeys in the cages in all stages of the disease, before and after. In fact a monkey would be exposed to the bites of the flies on the same day he was infected, so that the flies could drink the blood of the monkey during all stages of the period of incubation of the disease, for we do not yet know in what stage of the infection the virus appears in the blood at its maximum, or the best period for infecting these flies. Following this we exposed healthy monkeys to the bites of the same flies, and after several weeks' time these healthy monkeys came down with a disease which in all essential respects resembles anterior poliomyelitis. Out of twelve healthy monkeys so exposed, six of them now have symptoms of the disease, three of them in the virulent form. Of the other three monkeys, two are coming down, but one seems to have a milder infection than the other. This mild infection consists of trembling and weakness of the hand, and some weakness of the jaw which lasted about a week or so and then passed away. We cannot be sure whether that is true poliomyelitis or not until we are able to test the monkey subsequently. If it were poliomyelitis, that monkey will be 'immune.' In three of the six cases that came down with the disease, having been bitten by flies, there was some diarrhea. The disease in the monkey resembles more closely that which we see in children, rather than the disease we produce purposely experimentally by bringing the virus in direct association with the central nervous system. Of course, that may be only a coincidence, but it is interesting."

The work of Rosenau was repeated and confirmed during October, 1912, by Anderson and Frost[1] who summarize as follows: "Three monkeys exposed daily to the bite of several hundred Stomoxys, which at the same time were allowed daily to bite two intracerebrally inoculated monkeys developed quite typical symptoms of poliomyelitis eight, seven and nine days from the date of their first exposure."

In order to verify the findings of the above experiments and to secure further biological evidence if possible the writer, in coöperation with Dr. W. A. Sawyer,[2] undertook a special investigation of the problem, beginning in October, 1912. Believing it unwise to use flies collected out of doors these insects were reared for the purpose in an insectary. The importance of this precaution is made evident by the fact that flies captured out of doors in Berkeley were shown to transmit a pathogenic organism to a rabbit, infection undoubtedly having been acquired in nature. This infection resulting in abscess was successfully transmitted from rabbit to rabbit through the agency of the Stomoxys fly.

"In Rosenau's announcement he stated that the monkeys showed symptoms of poliomyelitis several weeks after the flies, which were biting them frequently, had had their first opportunity to receive infection from sick monkeys. This would allow abundant time for a definite biological change in the virus, preparing it, during the incubation in the fly as intermediate host, for successful inoculation into the warm-blooded monkey. Such a process seemed not an improbable explanation of the results when we considered that Rosenau was dealing with a blood-sucking insect and a disease in which the blood had been shown to have very low infectivity on direct inoculation. The symptoms of poliomyelitis in the experiments of Anderson and Frost appeared so soon after

[1] Anderson, John F., and Frost, Wade H., 1912. Transmission of poliomyelitis by means of the stable fly (*Stomoxys calcitrans*). U. S. Pub. Health Repts., Vol. XXII, No. 43, Oct. 25, 1912.

[2] Sawyer, W. A., and Herms, W. B., 1913. Attempts to transmit poliomyelitis by means of the stable fly (*Stomoxys calcitrans*). Journ. Amer. Med. Assoc., Vol. LXI, pp. 461–466.

the first possible transference of infectious material that in all probability the process consisted of a mechanical transference of blood or other infectious material taken up by the flies while repeatedly piercing the skin. The extreme shortness of time available, in their experiments, for incubation of the virus in the fly is apparent when we consider that, in the interval of nine or ten days, we must allow also for the development of the virus in the original inoculated monkeys and for the incubation period in the monkeys infected by the flies." (Sawyer and Herms, *loc. cit.*)

Assuming the accuracy of the work of Rosenau and Anderson and Frost, it seemed advisable to plan the experiments so as to secure, if possible, an answer sooner or later to each of the following questions:

1. Is the Stomoxys fly merely a mechanical carrier of poliomyelitis or is it an intermediary host?
2. If it is an intermediary host how much time must elapse after biting before it can infect another animal?
3. How long does the fly remain infective?
4. How soon after infection does the experimental animal become infective to the fly and how long does the animal remain infective to the fly?
5. Does the severity of the infection increase with the number of bites of the fly?
6. What is the percentage of infected flies in nature?
7. Do other biting insects carry this disease?
8. Can other animals be inoculated by the Stomoxys fly and serve as carriers or receptacles of the disease, *e.g.* chickens, rabbits, guinea pigs, rats, mice, pigs, dogs, cats, horses and cattle?
9. What are the best methods to exterminate the Stomoxys fly?
10. What precautions are necessary to prevent the existing flies from coming in contact with infectious patients and carrying the disease to other individuals?

A series of seven experiments was conducted covering a period of about nine months and involving the use of about four thousand laboratory reared flies, a large number of monkeys, rabbits and other rodents. The experiments were carefully planned and every precaution was taken to bring about accurate results. In the first experiment approximately 1750 flies were used, applying these to the animals in bobbinet-covered glass jars (quarts), 50 flies to a set (Fig. 146). A rhesus monkey was inoculated intracerebrally with 2 cc. of a suspension of Flexner virus, and the first set of flies was placed on this animal immediately after inoculation and after ten minutes' feeding transferred to a healthy monkey. The next day new sets of flies were used and again transferred to the same monkey, and those flies which had bitten the sick monkey on the previous day (24 hours ago) were placed to bite another unused monkey. In this way new flies were used each day and transferred immediately to the first healthy monkey; thus this animal always received flies that had fed for the first time on the sick monkey and transferred immediately. The second healthy monkey always received flies supposed to hold infection for 24 hours; the third animal, flies of 48 hours standing; the fourth animal, flies of four days; the fifth animal, flies of nine days; the sixth animal, flies of seventeen days; the seventh, flies of thirty days; and the eighth received daily all the survivors of the entire series until all the flies were dead.

Between monkey feedings until the last animal was used, the flies were kept alive by allowing them to feed on rabbits every other day, a new rabbit being used each time. The rabbits remained healthy.

In the above experiment all the monkeys remained healthy except two; namely, the first one which received the virus, and that animal died on the fourth day of typical poliomyelitis, and the seventh animal, which died of acute pneumonia.

Except in cases of immediate transfer when only ten minutes of feeding was permitted, the flies were given ample opportunity to feed

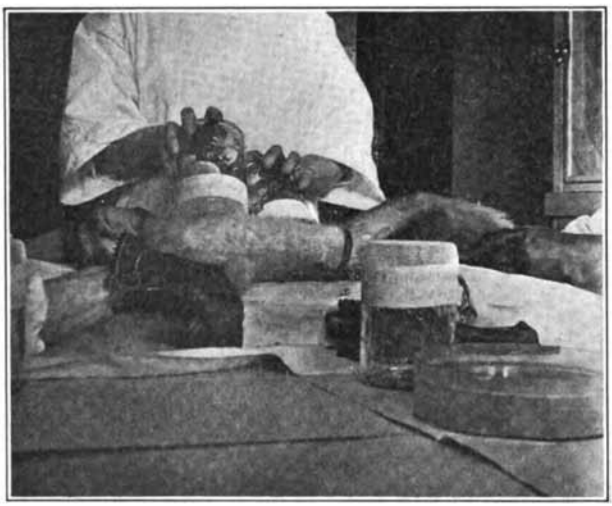

FIG. 146. — Showing jar method of feeding Stomoxys flies on monkeys. The jars are covered with bobbinet and sealed with adhesive plaster. The flies thrust their proboscides through the meshes and thus come in contact with the monkey.

until satisfied (normally from 20 to 30 minutes) and ordinarily the flies fed well.

In the second experiment an immobilized inoculated monkey was placed in a screened fly cage (16″ × 28″ × 18″) with 500 Stomoxys flies. This animal remained in the cage with the flies for two hours, after which it was removed and a healthy monkey substituted (also immobilized). The second animal remained in the cage with the flies also for a period of two hours. This was repeated daily until the inoculated monkey died of poliomyelitis, after which the healthy animal was returned to the cage daily until all the flies were dead. The results proved negative.

In the third experiment the flies in jars as before to the number of about 600 were kept continuously under higher temperatures in the insectary, — temperature ranging from 23° to 26° C. The flies were applied for three minutes to the belly and chest of a diseased (poliomyelitis) monkey and then three minutes to the belly, chest and face of a healthy monkey, and thus exchanged back and forth at three-minute intervals until all flies had had a good chance to feed daily. After the death of the diseased monkey the flies were fed daily on the healthy monkey until all the flies were dead. The results were negative.

In the next experiment a fly filtrate, made of flies which had one hour previously fed on a monkey at the height of the disease, was inoculated, intracerebrally, into a healthy monkey with negative results, as also did a filtrate made from flies having fed four days previously.

In the fifth experiment large numbers of flies were applied daily at three-minute intervals between a poliomyelitis monkey and two healthy monkeys and continued daily on the latter after the diseased monkey died. The results were negative as before.

It was thought that possibly the results of the previous investigators had been due to the access of the flies to infectious material on the surfaces of the diseased monkeys and about their body orifices, hence a parallel experiment to the one above cited was undertaken with the difference that the abdomen and chest of the diseased monkey were painted, before the fly feedings, with a mixture of his saliva, his feces, and (late in the disease) his nasal washings in physiological salt solution. Even so the results were negative. Later, after the death of the diseased monkey, an emulsion of the highly infectious brain tissue was used in place of the mixture of feces, saliva and nasal secretions. The brain emulsion was painted on a normal monkey after which flies were applied and transferred as before to two other normal monkeys, all remaining well. Poliomyelitis had not been produced in a well monkey by stable flies even when they had to drive their proboscides through a layer of highly infectious brain tissue in order to pierce the skin, and the same flies did not transmit the disease on subsequent bitings of two other monkeys.

Conclusions. — From the above-cited experiments the following conclusions were drawn:

1. In a series of seven experiments in which the conditions were varied we were unable to transmit poliomyelitis from monkey to monkey through the agency of the stable fly.

2. Further experiments may reveal conditions under which the stable fly can readily transfer poliomyelitis, but the negative results of our work and of the second set of experiments of Anderson and Frost [1] lead us to doubt that the fly is the usual agent in spreading the disease in nature.

3. On the basis of the evidence now at hand we should continue to isolate persons sick with poliomyelitis or convalescent, and we should

[1] Anderson, John F., and Frost, W. H., 1913. Poliomyelitis: Further attempts to transmit the disease through the agency of the stable fly (*Stomoxys calcitrans*). U. S. Pub. Health Reports. Washington, May 2, 1913, Vol. XXVIII, pp. 833–837.

attempt to limit the formation of human carriers and to detect and control them. Screening of sick rooms against the stable fly and other flying insects is a precaution which should be added to those directed against contact infection, but not substituted for them.

4. The measures used in suppressing the house fly are not applicable to the control of the stable fly owing to its different breeding habits and food supply.

Control. — The more important breeding places of the Stomoxys can be destroyed by removing the moist feed wastes from feeding troughs and from stalls, stables, etc., and scattering this material so that it dries out quickly. Considerable moisture is necessary for the development of the larvæ, therefore dry material is not suitable. Weeds, lawn cuttings, vegetables, rubbish, decaying onions, etc., must not be permitted to accumulate in piles long enough to decay and accumulate moisture. The absence of stables does not insure against the Stomoxys fly even though it is called the stable fly. The commonest fly around stables is the house fly, while the Stomoxys may be entirely absent. This fly is near stables because of the blood of horses, cattle, etc., and not because suitable breeding material is commonly found there. Open country without stables is sometimes over ridden with these biting flies.

Bishopp (*loc. cit.*) has shown that straw stacks (oats and wheat) are important breeding places of the Stomoxys fly, hence he recommends "that the straw for feeding and bedding purposes be baled and stored under cover. Where this is not practicable the stacks should be rounded up so as to make the top largely rain proof and the sides nearly vertical."

Repellent decoctions on domesticated animals only give temporary relief. Bishopp recommends as the most efficacious "a mixture of fish oil, oil of tar, and oil of pennyroyal with a little kerosene added."

Screening barns is recommended where flies are abundant.

Systematic. —The genus Stomoxys includes about ten species, of which *St. calcitrans* Linn. is the type, also the best known and most widely distributed species, occurring commonly on every continent.

Other species, all occurring in smaller numbers in restricted localities in Africa, are: *St. glauca* Grünb.; *St. inornata* Grünb. and *St. nigra* Macquart, which is said also to occur in the Philippines, but is considered a doubtful species by Grünberg.

C. The Horn Fly

Family Muscidæ, Genus Hæmatobia

Introduction. — *Hæmatobia serrata* R. Desv. (=*Lyperosia irritans L.*) is commonly called the horn fly, also known as the Texas fly. The former name is applied because this fly has the habit of clustering, often in great numbers, at the base of the horns of cattle. Though many believe the fly to injure the horn, there is no foundation for this belief. The position is probably only sought because it affords a safe resting place, especially at night.

As a cattle pest the horn fly has few if any equals; indeed, in the San Joaquin Valley (California) this fly is regarded as the most serious pest. The horn fly is a comparatively recent introduction into the United States from Europe, where it has been an important cattle pest for many years. According to the U. S. Bureau of Entomology it was first reported in the fall of 1887 from Camden, N. J. appearing during the following year in Maryland and Virginia, probably having appeared in Philadelphia in 1886 and by 1892 was found over the entire continent from Canada to Texas and from Massachusetts to the Rocky Mountains. California cattle men state that it made its appearance in this state in about 1893–1894. It appeared in Honolulu, Hawaii, in 1897.

Characteristics. — The horn fly is about half the size of the common house fly, *i.e.* about 4 mm. long. It has much the same color and in most other respects resembles the Stomoxys fly. The mouth parts (Fig. 147) are as in Stomoxys except that the labium is relatively heavier and the palpi are almost as long as the proboscis, are flattened and loosely ensheath the same. The arista is plumose dorsally. The wing venation is as in Stomoxys.

FIG. 147. — Side view of head of the hornfly, *Hæmatobia serrata.*

These flies appear early in spring and become most abundant in late summer and autumn. Both cattle and horses are attacked, but most especially the former. When at rest on the animal or elsewhere the wings lie flat on the back and fold rather closely, but when the fly bites, the wings are spread and the insect stands perpendicularly, almost hidden between the hairs of the host. Apparently the habit of resting at the base of the horns is only developed when flies are overabundant.

Life History. — The horn fly deposits its eggs chiefly, if not exclusively, on freshly passed cow manure. The fly is seen to dart from the animal and deposit its eggs in groups of four to seven, or singly, on the surface of the dung. The eggs are relatively large (1.3 to 1.5 mm.), larger than the eggs of Stomoxys, they are reddish brown in color, hence not easily seen on the cow dung. Under laboratory conditions, at least, few eggs are deposited by the females, — rarely over twenty. At a temperature of 24° to 26° C. the eggs hatch in twenty-four hours.

The larvæ burrow beneath the surface of the droppings, reaching full growth in from three to five days when they crawl underneath into drier parts and pupate. The pupal period requires from six to eight days. Hence the entire life history (Fig. 148) from the egg to the adult requires from ten to fourteen days at a temperature of from 24° to 26° C.

Damage Done. — The damage occasioned by the horn fly is chiefly through irritation and annoyance which results in improper digestion and disturbed feeding, thus producing loss of flesh and reduction of milk in dairy animals. Dr. James Fletcher estimated the loss in Ontario and Quebec at one half of the product of meat and milk. Range animals literally run themselves thin in trying to get away from these pests.

The actual loss of blood must be considerable when literally thousands of these flies attack an animal. The weakened condition thus produced lays the animal liable to disease. From ten to twenty-five minutes are required for the fly to fully engorge itself; during this time the fly withdraws and reinserts its proboscis in the same puncture many times as in a pumping motion. Much undigested blood is discharged from the anus of the fly while in the act of feeding.

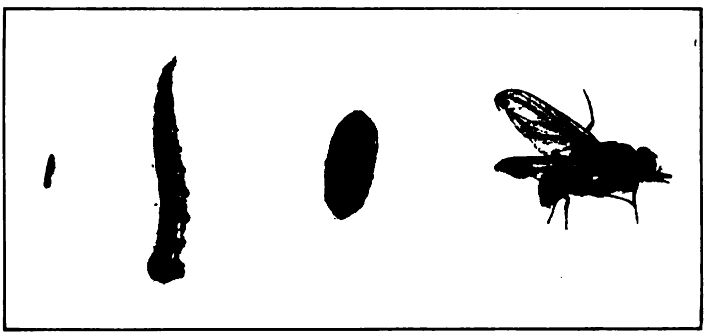

FIG. 148. — Life history of the "horn fly," *Hæmatobia serrata*. × 4.

Finally, though not absolutely proved, except through inference, the horn fly must certainly have the power of transmitting infectious blood diseases, such as anthrax. This problem has as yet not been touched by investigators.

Control. — The most effective method to prevent the multiplication of the horn fly is to scatter the droppings from cattle with a rake or other implement or simply by dragging a dry branch over the field. Hogs allowed to run with the cattle serve this purpose very well. The manure thus scattered dries out quickly and the larvæ if present perish owing to the fact that they require much moisture for development. The writer has seen this method applied most successfully in various parts of California where the dry summer favors this mode of handling the fly. On wide ranges this method is impracticable, but in connection with dairies it is entirely feasible. Piles of cow manure removed from stables afford a good breeding place for the Stomoxys fly, especially when straw predominates, but the horn fly is not favored in this way to any great extent. The manure should either be stored temporarily in fly-tight bins like horse manure, or spread on the field at once, or else placed in containers with water to liquefy the manure, the containers to be covered.

Animal *sprays* used as repellents are of various kinds and of various efficiencies. Few sprays remain effective for longer than a day or so. Almost any oily, greasy substance is useful, but animals thus treated in the presence of dusty roads and pasture become very filthy in a short time. The usual ingredient in sprays for this purpose is fish oil or train oil, though petroleum sprays are also commonly used. The latter are not to be recommended for use on very hot days.

Petroleum sprays are used in the form of kerosene emulsion (crude petroleum, 2 gallons, $\frac{1}{2}$ pound soft soap, 1 gallon soft water) one part to five parts of water. The Kansas Experiment Station (Press Bulletin No. 65) recommends the following mixture as both cheap and efficient; resin (pulverized), 2 parts; soap shavings, 1 part; water, $\frac{1}{2}$ part; fish oil, 1 part; oil of tar, 1 part; kerosene, 1 part; water, 3 parts. The resin, soap, fish oil and $\frac{1}{2}$ part water are boiled together until the resin is dissolved, then add the three parts of water and finally the kerosene and oil of tar. The mixture must be thoroughly mixed and boiled for fifteen minutes. The cooled mixture is then ready for use as a spray.

The application of the spray is done by means of a knapsack spray pump or other hand sprayer. One application seldom remains effective longer than three days, usually only a few hours. The addition of crude carbolic acid and sulphur is strongly recommended.

Washburn [1] states that " very fine tobacco dust sifted into the hair on the backs and where it will find lodgment, and the above wash (a mixture of fish oil and crude carbolic acid) applied to other parts which will not hold the dust, will obtain good results."

Smaller herds can be treated with ease by driving the animals through a narrow passageway, applying the spray as they pass between. On a larger scale it has been shown that dipping vat methods can be satisfactorily applied. The following is quoted from Circular No. 115, U. S. Department of Agriculture, Bureau of Entomology: " During the last three years, Mr. J. D. Mitchell, an agent of the Bureau, working with Mr. W. D. Hunter in Texas, has, in a study of the requirements for horn fly control, found that by a very simple modification of the ordinary dipping vat a very large percentage of the flies on cattle can be destroyed, with the consequent very notable limiting of the loss from the fly pest. With the vats as ordinarily constructed, most of the flies abandon the animal at the moment it plunges into the vat and escape, and go to other animals, and ultimately with the drying of the dipped animal return to it. Mr. Mitchell found, however, that by putting a splash board near the top of the vat on either side, about four feet above the level of the dip, the water thrown up violently as the animal plunges in, is caught by

[1] Washburn, F. L., 1905. Diptera of Minnesota: two-winged flies affecting the farm, garden, stock and household. Univ. of Minnesota Agr. Exp. Sta., Bull. No. 93.

these splash-boards and is thrown back as a spray, filling the air space above the animal and drenching and destroying the flies in their effort to escape. The few of the horn flies that may escape, together with those which abandoned the animal at the entrance to the vat, were observed to hover or settle on the chute fence, and many would alight on the next animal coming along. He also found that where the animals have been heated in corralling and getting them into the chute the flies stick much closer and are much less apt to take quick flight, thus insuring the capture of a larger percentage of them by the dip and spray." An oily dip must, of course, be used for this purpose.

CHAPTER XVI

MYIASIS

Flesh Flies, Botflies, Warble Flies, etc.

Myiasis is a term referring to the presence of and resultant disturbances traceable to insect larvæ, primarily Diptera, in the intestine (*intestinal myiasis*), stomach (*gastric myiasis*), subcutaneous tissue (*dermal* or *cutaneous myiasis*), muscles (*muscular myiasis*), frontal sinuses (*nasal myiasis*), or ears (*auricular myiasis*) of vertebrate animals. The responsible insects may relate to myiasis in a more or less accidental manner, as is the case with certain root maggot flies, or they may be obligatory parasites, as is true of the bot and warble flies.

Dipterous Larvæ. — The larvæ of Dipterous insects are footless and are commonly called *maggots*. Owing to the environmental setting of the parasitic species they may be mistaken for " worms " and are commonly so designated. Owing to differences in prophylactic measures insect larvæ and helminths should be carefully distinguished. The dipterous larvæ are as a rule short and plump, measuring from 5 to 35 mm. in length (less in very young larvæ), and from 1 to 12 mm. in diameter; they are more or less cylindrical and tapering in form; are distinctly segmented, with ordinarily 11 or 12 visible segments (Fig. 13). All insect larvæ (as well as adults) possess an internal system of tracheated tubules, the respiratory system, which worms do not possess, hence with even a very minute portion of the parasite at hand, one can readily determine whether the specimen is insectan or not.

All nematode worms with which maggots might most easily be confused are non-segmented. Annelids with which insect larvæ might also be confused owing to their cylindrical, often plump form and their common segmentation, are easily distinguished from the fact that the former possess a larger number of segments (certainly over 20) and are devoid of tracheal tubules. Other important zoölogical characters are, of course, recognized.

A. The Flesh Flies

Order Diptera, Family Sarcophagidæ

Adult Characteristics. — The larvæ or maggots of the flesh flies are met with most frequently in myiasis of all forms. The adult flies are commonly known as blowflies. The great majority of the species deposit their rather conspicuous glistening white eggs on meat, dead animals, excrement or decaying vegetable matter; several species, notably the gray flesh flies (Sarcophaga) deposit living young. The blowflies are commonly included with the Muscidæ, but by following Girschner's classification based on thoracic bristles all of the typical flesh-feeding flies are conveniently classed among the Sarcophagidæ. The Sarcophagids are as a rule large flies, the smallest being about the size of the house fly; the wing venation is of the Muscid type; in color they vary from a bright metallic green and blue to gray; the thorax is more or less densely covered with bristles or heavy hairs (the Tachinid flies with which the Sarcophagids are most easily confused have tufts of very long spines on the tip of the abdomen, and the arista is bare).

Chrysomyia (*Compsomyia*) *macellaria* Fabr. is the most important member of the family.[1] This fly is commonly known as the *Texas screw worm fly*, probably because the larva is provided with intersegmentally arranged short spines and papillæ which give it a more or less screw-like appearance. The fly (Fig. 149) varies in size from 10 to 13 mm., dependent upon the growth of the larva; the ground color is a metallic green, with three longitudinal dark stripes on the thorax; the head is reddish to yellowish brown; the wings, when at rest are commonly folded scissors-like over the abdomen; the wing venation is similar to that of the house fly (*Musca domestica*).

Fig. 149. — *Chrysomyia macellaria*, the Texas screw worm fly. × 3.5.

The screw worm fly is typically a North and South American fly ranging from Patagonia to Canada.

Life History. — The screw worm fly over-winters most commonly in the pupal stage, but, no doubt, also hibernates as an adult as do the bluebottle and green-bottle flies. *Chrysomyia macellaria* deposits eggs normally within its southern range, the time for hatching varying from less than an hour to twelve or more hours. But there is some difference of opinion as to its habits in its northern range. The writer has carried on careful observations on this fly during several summers along the southern border of Lake Erie and has never observed this fly to lay eggs. Living young were invariably deposited. Others (notably Hine) maintain that eggs are deposited. It is quite possible that the latter is true earlier in the summer.

The eggs or larvæ to the number of 200 to 500 are deposited on dead animals ordinarily, or in wounds or sores of domesticated or wild ani-

[1] For a detailed account of the ecological relationships of the Sarcophagidæ the reader is referred to the writer's work "An ecological and experimental study of Sarcophagidæ, etc." Journ. of Exp. Zoöl., Vol. 4, No. 1, pp. 45–83. Also "The sensory reactions of Sarcophagid flies, etc." Journ. of Exp. Zoöl., Vol. 10, No. 2, pp. 167–226.

mals. Human beings are frequently attacked in the nostrils. The growth of the larvæ is very rapid, full size being reached in three days under optimum conditions. The fully grown maggots vary from 12 to 15 mm. in length; food shortage (except when very great) as a rule only results in smaller larvæ and smaller flies.

When fully grown the larvæ leave the carcass or wound, bury themselves in loose earth or débris immediately beneath or near by, and enter the pupal stage in two or three days. The pupæ are chestnut-colored, barrel-shaped, rather rough and fairly characteristic, measuring from 5 to 8 mm. in length. Under optimum conditions the pupal stage requires four days.

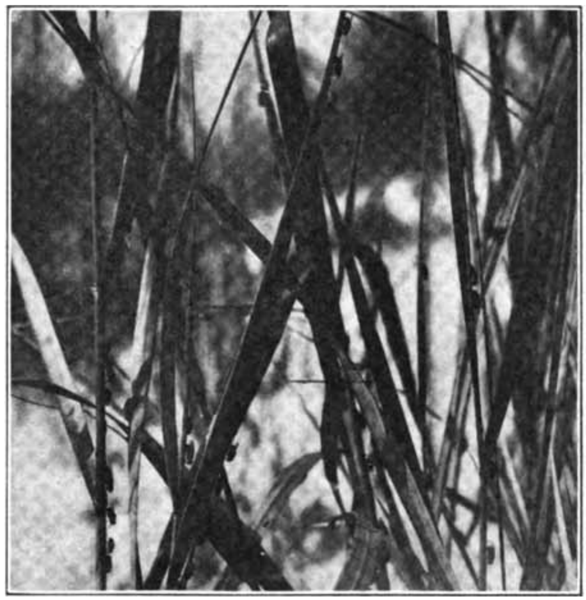

FIG. 150.—Texas screw worm flies just emerged from the pupa cases. A dead animal near by furnished food for the larvæ, pupation took place in the sand underneath the carcass. The newly emerged flies have crawled up on the grass and will soon be ready to fly away. Note characteristic resting attitude, with head down.

On emergence from the pupal cases the flies crawl out of the sand or dirt and climb up near-by grasses, weeds or shrubbery, where the wings are spread. The screw worm fly at this time almost invariably turns about with its head downward after it has reached a resting place. (Fig. 150.) Thus one often finds great numbers of flies in some restricted spot without an apparent explanation for their presence. The total life history of the screw worm fly from egg (or maggot) to imago is nine days at its shortest to two weeks and over under less favorable conditions.

As Affecting Man the attacks of this fly are largely limited to individuals suffering from nasal catarrh or unclean from vomit or with open sores or wounds. Sleeping individuals or persons in a drunken stupor are most liable to be attacked, although the fly has been known to dash successfully into the nostrils of wide-awake individuals, in which case the fly is usually not permitted to remain in the nostrils long enough to oviposit. Even so it is wise to properly syringe the nasal passages.

The following quotation will sufficiently explain the nature of the injury produced. (See Osborn, 1896, pp. 127–128, quoting Richardson in *Peoria, Ill. Med. Mo.* for February, 1883.)

"While traveling in Kansas in the latter part of last August, a citizen of this place had the misfortune to receive while asleep a deposit of eggs from this fly. He had been troubled for years with catarrh, hence the attraction to the fly. He returned home a few days after the accident and shortly after began complaining of a bad cold. Growing rapidly worse, I was called to attend him. Monday, my first day, his appearance was that of a man laboring under a severe cold. Had slight congestion of the lungs, and moderate fever. His nose seemed greatly swollen and he complained of a smarting, uneasy feeling in it, and general misery through the head. Gave him treatment to relieve the congestion and fever. Tuesday, saw him again. His nose and face were still swollen, and in addition to the other symptoms he was becoming slightly delirious and complained a great deal of the intense misery and annoyance in his nose and head. A few hours after, I was sent for in haste with the word that something was in his nose. I found on examination a mass of the larvæ of this fly (or 'screw worms' as they are commonly called in the South) completely blocking up one nostril. On touching them they would instantly retreat *en masse* up the nostril. Making a 20 per cent solution of chloroform in sweet milk I made a few injections up both nostrils, which immediately brought away a large number, so that in a few hours I had taken away some 125 of them. By Wednesday evening erysipelas had begun, implicating the nose and neighboring portions of the face. Another physician was called. By continual syringing with a strong antiseptic solution of salicylate of soda, bicarbonate of soda, and carbolic acid we hoped to drown out the remaining larvæ. But they had by this time cut their way into so many recesses of the nose and were so firmly attached that we were unable to accomplish much. Finally we resorted to the chloroform injections, which immediately brought away a considerable number. Friday I was able to open up two or three canals that they had cut, extracting several more that had literally packed themselves, one after another, in these fistulous channels. His speech becoming suddenly much worse, I examined the interior of his mouth and found that a clear-cut opening had been made entirely through the soft palate into his mouth and large enough to insert the end of a common lead pencil. Saturday the few remaining larvæ began changing color and one by one dropped away. On Sunday for the first time hemorrhage from both nostrils took place, which continued at intervals for three days, but was not at any time severe. On this day the patient began to improve, the delirium and erysipelas having subsided, leaving but little or no annoyance in his head. In a few days he became able to go about home, and even to walk a distance of half a mile to visit a friend and return. But while there he began complaining of a pain in the neighborhood of his left ear, apparently where the eustachian tube connects with the middle ear. It proved to be an abscess. Being already so reduced by the first attack he was unable to withstand the second, and died after an illness of nearly three weeks, completely exhausted by his prolonged sufferings. Three days before his death the abscess discharged its contents by the left nostril. The quantity of pus formed was about 2½ ounces (78 grams).

"In all about 250 larvæ were taken away from him during the first attack, and, as the visible results, not only had they cut the hole through the soft palate, but had also eaten the cartilage of the septum of the nose so nearly through as to give him the appearance of having a broken nose. The case occupied, from the first invasion of the fly to its final result, nearly two months. He doubtless would have recovered but for the formation of the abscess, which, from all the symptoms, was caused by one or more of the larvæ having found their way up the left eustachian tube."

As Affecting Domesticated Animals. — According to Osborn [1] cattle suffer most from the ravages of screw worms, in which they occur in wounds from horns, castrating, spraying, branding, dehorning, barbed wire injuries, and often where ticks have burst on the brisket, flank or just behind the udder of cows. They often occur in the vulvæ of fresh cows, especially if there has been a retention of the placenta or afterbirth. Young calves are almost invariably affected in the navel, and often in the mouth, causing the teeth to fall out.

Horses and mules are not so often attacked, and if so, the maggots are usually found in barbed wire injuries, and occasionally in the sheaths of horses and the vaginæ of mares and the navels of colts.

Hogs on the other hand are more liable to become affected than horses, since they are frequently wounded by dogs and by fighting or there may be barbed wire injuries, wounds from castration, etc.

"Sheep are attacked when injured by dogs; or when the sheep are in poor condition the eggs are laid upon the wool, and when the larvæ hatch they immediately bore into the skin. In many cases the sheep are attacked within the nasal cavities and the worms eat into the head." The reader is warned against confusing these maggots with the true head maggot (*Œstrus ovis*).

Other Flesh Flies. — The larvæ of several species of flesh flies are frequently met with in gastric and intestinal myiasis. This is accounted for by the presence of very young maggots in meats which are eaten cold and not carefully masticated. Nausea and gastric disturbances may be traceable to this form of accidental myiasis. Owing to the small amount of oxygen available the growth of the larvæ must needs be very slow. Larvæ brought to the attention of the writer have been seldom more than 4 or 5 mm. long.

The flesh flies deposit their eggs commonly on cold meat, particularly pork, if exposed to flies. The eggs hatch in from eight to twenty-four hours under summer conditions and the larvæ grow rapidly.

The larvæ of these several species also occur frequently in wounds in domesticated animals and man, producing injury similar to that of the screw worm.

The larvæ of the blowfly or bluebottle, *Calliphora vomitoria* Linn. and *C. erythrocephala*, Mg. (Fig. 117*e*) are most commonly met with. The two species of flies are not usually differentiated, the two names being applied indiscriminately. *C. vomitoria*, however, has black genæ with golden red hairs, while *C. erythrocephala* has fulvous genæ with black hairs. The eggs of these species hatch in from six to forty-eight hours, the growing larvæ feed on the flesh for from three to nine days, after which the fully grown larvæ leave the food and bury themselves in loose earth. This period (prepupal period) lasts from two to seven days, commonly four, after which pupation takes place. The pupal period varies considerably according to temperature, lasting from ten

[1] Osborn, Herbert, 1896 (*loc. cit.*).

to seventeen days, commonly eleven days. Thus the life history of the blow fly requires from sixteen to thirty-five days, commonly twenty-two days. The life of the adult is about thirty-five days on an average.[1]

Lucilia cæsar Linn. (Fig. 117*d*), the greenbottle fly, is not so commonly found indoors and is typically a scavenger fly. The life history of this species is somewhat shorter than that of the bluebottle. The egg stage requires from six to forty-eight hours; the growing (feeding) larval stage requires from three to seven days, commonly five days; the prepupal period, commonly six days; and the pupal period from eight to thirty-four days, commonly twelve days, giving a total of from sixteen to sixty days and over, commonly twenty-four days. Under optimum conditions this fly invariably *requires* fifteen days for its metamorphosis; the average longevity of the fly is about thirty days.

Lucilia sericata, Mg. is popularly known as the "sheep maggot fly" owing to its frequent occurrence on sheep. This fly resembles *Lucilia cæsar* very closely, and its larvæ resemble the larvæ of the latter even more closely. The female deposits her eggs commonly in the soiled wool of lambs and sheep. Animals suffering from diarrhea are particularly subject to attack. The newly hatched larvæ live either in the matted wool next the skin or burrow under the skin particularly at points that have been injured by ticks or in other ways.

The damage done by the larvæ is often quite great. The metamorphosis and time requirement for the larval and pupal periods are quite similar to *Lucilia cæsar* and the damage done is similar to that of *Chrysomyia macellaria. Phormia regina* Meig. is also an important sheep maggot fly in California.

Fig. 151. — The Congo floor maggot, *Auchmeromyia luteola.* × 2.5.

Sarcophaga sarraceniæ Riley is a typical flesh fly, has the appearance of an overgrown house fly, but is lighter gray, has a spiny thorax, brighter reddish brown eyes and is viviparous. It resembles very closely the larger species of parasitic Tachinid flies, but has not the strongly developed terminal abdominal spines. The young are deposited on meat, or if extruded in the vicinity of meat not accessible to the fly, the larvæ crawl to the food. The larval stage under optimum conditions requires about five days, and the pupal period about thirteen days.

Several African species of flesh flies are commonly referred to in the literature on myiasis, among them *Cordylobia anthropophaga,* E. Blanch., the "tumbu fly,' the larvæ of which burrow beneath the skin, developing there as do the larvæ of the warble fly, *Hypoderma.* It is said that babies are particularly liable to be attacked by the "tumbu fly." Austen describes it as being a "thickset, compactly built fly, of an average length of

[1] Herms, W. B., 1911. The photic reactions of Sarcophagid flies, etc. Contributions from the Zoöl. Lab. of the Mus. of Comp. Zoöl., Harvard, No. 217.

about $9\frac{1}{2}$ mm. . . . Head, body and legs straw color. . . ." Another species commonly found in the same locality with the above is *Auchmeromyia luteola*, Fabr. The larva is a blood-sucker and is known as the "Congo floor maggot." (Fig. 151.) The two species are said to resemble each other closely but Graham-Smith[1] states that "the two species may be distinguished by the fact that in *A. luteola* the eyes are wide apart in both sexes, the body is narrower and more elongate, the hypopygidium of the male is in the form of a conspicuous, forwardly directed hook, for which the ventral half of the penultimate segment of the abdomen serves as a sheath; and lastly, by the fact that the second abdominal segment in the female is twice the length of the same segment in the male. . . ."

"The full-grown larva is a fat, yellowish white maggot, 12 to $12\frac{1}{2}$ mm. in length, bluntly pointed at the anterior or cephalic extremity, and truncate behind; its greatest breadth (on the sixth and seventh segments) is 5 mm. The body consists of twelve visible segments, the divisions between which are strongly marked, except between the cephalic and first body segment (the latter of which bears the anterior or prothoracic stigmata, or respiratory apertures), and between the eleventh and twelfth segments. On the underside of the cephalic segment the tips of the black paired mouth hooks may be seen protruding, while in a slight depression in the flattened posterior surface of the twelfth segment are situated the paired posterior stigmatic plates. In the adult larva the slit-like apertures in these plates are not very easy to distinguish, but in a maggot in the second or penultimate stage, it is seen that each plate bears three ridges of tawny colored chitin; these ridges run obliquely downwards and outwards, at an angle of 45° from the median line, and, while the median ridge on each plate is nearly straight, the other two ridges are characteristically curved, resembling inverted notes of interrogation, with the concavity directed towards the median ridge. The segments of the body are transversely wrinkled on the dorsal and ventral surfaces (especially on the latter), and puckered on the sides. From the third to the eleventh segment the body is thickly covered with minute recurved spines of brownish chitin (darker in the case of larvæ ready to leave the host), usually arranged in transverse series or groups of two or more, which can be seen to form more or less distinct, undulating or irregular, transverse rows. These spines will be described in somewhat greater detail below.

"Above and to the outer side of each mouth hook is an antenna-like protuberance, which, as in the case of the larva of the blowfly (*Calliphora erythrocephala* Mg.), exhibits a pair of light brown, ocellus-like spots, or rather papillæ, placed one above the other. In a small larva, 5 mm. in length, from Lagos, the papillæ are very clearly visible; each papilla is surrounded by a ring of pale brownish chitin, and its shape, when viewed from the side, is exactly that of a muzzle of an old-fashioned muzzle-loading cannon.

"This small larva also shows on the basal segment of each antenna, or antenna-like protuberance, below and a little to the outer side of the mouth hook, a prominence bearing a series of about six small, brown tipped, chitinous spines. In the same larva the spines on the body are most conspicuous, and most strongly developed and chitinized, on the fifth, sixth and seventh segments. The tenth and eleventh segments are also covered with spines, but, since the chitin of which they are composed is not tinged with brown, these segments appear bare.

[1] Graham-Smith, G. S., 1913. Flies in relation to disease, — non-blood-sucking flies. Cambridge University Press, xiv + 292 pp.

In the adult larva also, the spines of the tenth and eleventh are less conspicuous than those on the preceding segments; on the twelfth segment, which bears the posterior stigmatic plates, the spines are very minute. Fully chitinized spines are dark brown, but this color is generally confined to the apical half of the spine, or may be absent from the extreme base. In shape each spine is a short cone, with the apex recurved, pointing towards the hinder part of the body. The spines are broad at the base in proportion to their length, and not infrequently, especially on the under side of the body, are bifid at the tip. They are closest together and most strongly developed on the anterior portion of each segment, becoming smaller and showing a tendency to disappear towards the hind margin. They are arranged in irregular transverse rows, which are usually seen to be composed of from two to five spines, placed side by side.

"In the adult larva the median area of the ventral surface of the segments five (or six) to eleven inclusive is marked with a series of three transverse ridges, which are most prominently developed on the seventh and following segments. On each segment the foremost ridge is the shortest; next in length comes the hindmost, and the middle ridge is the longest of the three, curling round the posterior ridge at each end. Similar but less strongly marked ridges are seen on the dorsal surface.

"*Puparium.* Of the usual barrel-shaped Muscid type. Average dimensions: length 10½, greatest breadth, 4¾ mm. Though at first of a ferruginous or light chestnut tint, the puparium gradually darkens until it becomes 'seal-brown' or practically black."

Manson (*loc. cit.*) states that the fly deposits its eggs in the dust-filled cracks and crevices of the mud floors of native huts, particularly in spots where urine is voided. The duration of the larval life has not been determined. The larvæ suck blood mainly at night. The pupal stage is said to require from two to three weeks.

Treatment for Nasal Myiasis in Humans. — Treatment for maggots in the frontal sinuses and other cavities must be given without delay, owing to the rapid growth of the maggots and their terrible destructive work. Injection of a myiacide is necessary. Some of the more useful remedies are "20 per cent solution of chloroform in sweet milk, a few injections up both nostrils," repeat until larvæ are expelled; or carbolic acid 2 per cent; or infusion of pyrethrum; or turpentine. A saturated solution of common salt will cause only a portion of the larvæ to be expelled but is not to be disregarded in the absence of more useful remedies, until a physician arrives.

Treatment for Animals. — After locating the point of infestation, indicated by purulent sores, or small eaten openings, surrounded by elevations which shift or disperse suddenly when touched, the expulsion of the maggots must be brought about by the introduction of an insecticide. Ordinarily a weak solution of carbolic acid (1½ to 2 per cent), pyrethrum infusion, chloroform, creolin or chloronaphtholeum is injected. This may be done as recommended by Francis by means of a machinist's oiling can. The larvæ must then be carefully scraped out and the wound dressed with pine tar or other curative agent. Pine tar will also act as a repellent against further attack by flies.

Preventive Measures. — To prevent immediate attack by flies, animals should be carefully examined for open wounds, wire fence cuts, etc., so as to apply treatment and repellents to prevent the deposition of eggs.

Inasmuch as the flies involved in myiasis breed very abundantly in dead animals, all carcasses should be burned without delay or buried deeply and the body liberally covered with "chloride of lime." Burning is preferable by far. Superficially buried carcasses are easily reached by the young maggots hatching from eggs deposited on the ground above the body. Proper and expeditious disposal of all dead bodies, such as rats, cats, dogs, or larger animals, also of slaughter house refuse, kitchen garbage, manures, etc., will certainly reduce the myriads of flies which are a menace to the health and well-being of both man and beast on the farm.

B. Anthomyid Flies

Order Diptera, Family Anthomyidæ

Characteristics. — The Anthomyid flies (Fig. 117*c*) are usually grayish in color, non-metallic resembling the house fly. The first posterior cell of the wings is broadly open. The mouth parts are of the house fly type. The larvæ are often vegetable feeders, either in living roots or in decaying vegetation, also in manures. The metamorphosis is complex as in the house fly.

Because the maggots of the Anthomyid flies are commonly found in onions, radishes, turnips and other roots and vegetation, their relation to human myiasis is easily understood, particularly when the vegetable is eaten uncooked. Several species of Anthomyid larvæ have been recovered in human cases, notably *Fannia* (*Homalomyia*) *canicularis*, *F. scalaris*, *Anthomyia radicum*.

Fannia (*Homalomyia*) *canicularis* L., commonly known as the *lesser house fly*, is frequently seen hovering in mid-air or flying hither and thither in the middle of the room. Where the common house fly is encountered most abundantly in the kitchen or dining room, particularly on food, the "little house fly" will be seen as commonly in one room as another, and very seldom actually on the "spread" table. The writer commonly observes a half dozen or more of these little flies dancing weirdly in the center of the lecture room midway between the floor and the ceiling. Various observers have estimated that this species constitutes from one to 25 per cent of the total population of flies in the house.

In size the species varies from 5 to 6 mm. Its color is grayish, resembling the house fly very closely. Hewitt describes the male, viz., " Head iridescent black, silvery white, especially around the eyes. The antennæ are blackish gray with non-setose arista. Palps black. The thorax is blackish gray with three indistinct black longitudinal stripes; the scutellum is gray and bears long setæ; the sides of the thorax are lighter. . . . The legs are black and the middle femora bear comb-like setæ below. The somewhat large squamæ at the bases of the wings are white and the halteres are yellow. . . . The head of the female is gray with a wide frons, black frontal stripe and gray sides. The longitudinal stripes of the thorax are faint and the abdomen, which is more pyriform than that of the male, has a slightly golden attachment."

The eggs of this species are deposited on decaying vegetable matter and excrement, particularly of humans, horses and cows. The larvæ emerge in about 24 hours and may be recognized as compressed, spiny organisms about 6 mm. long when full grown (Fig. 152*a*). The pupal period lasts about seven days under favorable conditions.

Fannia (*Homalomyia*) *scalaris* Fab., the latrine fly, is very similar to the foregoing. In size the two flies are about the same, if anything the latrine fly is somewhat the larger. The thorax and abdomen are bluish black, the antennæ and palpi are black as are the legs. The abdomen has a dark median stripe which, with segmentally arranged transverse bands produces a series of dorsal triangular markings. The middle tibia is provided with a distinct tubercle.

The eggs of this fly are deposited on excrement of humans, horses, cows, etc., also on decaying vegetable matter. The egg stage lasts about twenty-four hours, the larval stage about six days and over, and the pupal stage about nine days.

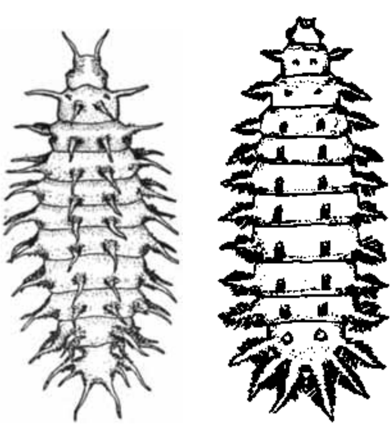

FIG. 152. — (*a*) Larva of *Fannia* (*Homalomyia*) *canicularis*; (*b*) Larva of *Fannia* (*Homalomyia*) *scalaris*. (Redrawn and adapted after Hewitt.) × 6.

While the larva of the "latrine fly" resembles the larva of the lesser house fly in general, it is readily distinguished. The single lateral protuberances are distinctly feathered (Fig. 152*b*).

Anthomyia radicum Linn. the root maggot fly of Europe, is described by Meade, according to Slingerland [1] viz.: "It may be recognized by its projecting face; by the scales of the base of the wings being unequal in size; by the thorax being black and marked in the male by two short, gray, narrow stripes; by the rather short, wide, somewhat pointed abdomen, with a longitudinal dorsal black mark, crossed by three transverse straight black stripes extending of an equal width to the margins; and by the third and fourth longitudinal veins of the wings being slightly convergent at their extremities. This inequality in the

[1] Slingerland, M. V., 1894. The cabbage root maggot, with notes on the onion maggot and allied insects. Cornell University Agr. Exp. Sta., Bull. No. 78, pp. 481–577.

size of the alular scales, the shape of the abdomen, the markings on the body, and the convergence of the third and fourth longitudinal veins of the wings are characters, any one of which would distinguish the male fly, at least, from the cabbage fly" (*Phorbia brassicæ*, Bouché).

Anthomyia radicum is a typical root maggot fly, its larvæ developing in the roots of radishes and other plants; Bouché records the maggots as developing in human excrement. According to Slingerland (*loc. cit.*) this author gives eight to ten days as the period required to pass through the egg and larval stage and two or three weeks for the pupal stage. Hewitt (*loc. cit.*) gives the egg stage at from eighteen to thirty-six hours, the larval stage at about eight days and the pupal stage about ten days.

The fully grown larva measures "8 mm. in length and may be distinguished by the six pairs of spinous tubercles surrounding the posterior end and a seventh pair situated on the ventral surface posterior to the anus. The tubercles of the sixth pair, counting from the dorsal side, are smaller than the rest and are bifid" (Hewitt). The ingestion of the larva with uncooked vegetables not thoroughly masticated, seems to be the mode of infection.

Relation to Gastric and Intestinal Myiasis. — Many cases of intestinal myiasis traceable to Anthomyid flies are recorded. (See Parasitology, Vol. 5, No. 3, pp. 161–174.) "The presence of these larvæ in the stomach is usually indicated by nausea, vertigo and violent pains; the larvæ in many cases are expelled by vomiting. If they occur in the intestine, they are expelled with the feces and their presence is signalized by diarrheal symptoms, abdominal pains or hæmorrhage caused by the traumatic lesions of the mucous membrane of the intestine which the larvæ affect" (Hewitt).

Mode of Infection. — As has already been explained, the eggs of these flies may be deposited upon decaying or even fresh vegetable matter or excrement, in which the larvæ develop. It seems quite probable that the young larvæ (possibly also the eggs) are taken into the stomach in uncooked food. It is also suggested (Hewitt) that the flies may deposit their eggs in or near the anus, particularly in the use of old-fashioned open privies. The larvæ on hatching are believed to make their way into the intestine.

Larvæ in the Urinary Tract. — Infestation of the urinary tract by larvæ of *Fannia canicularis* is by no means uncommon according to Chevril.[1] The expulsion of larvæ with the urine in both sexes has been recorded. Entrance into the urinary tract is undoubtedly gained by the larvæ through the genital openings (of females primarily), to which the adult flies have been attracted by secretions on exposure of these parts during sleep or drunken stupor.

[1] Chevril, R., 1909. Sur la myase des voies urinaires. Arch. de Parasitol., XII, pp. 369–450.

C. Rat-tailed Larvæ

Order Diptera, Family Syrphidæ

Characteristics. — The family Syrphidæ includes a very large group of flies, many of which are brightly colored, varying greatly in size. They are nearly all flower loving, feeding on nectar mainly. Only one genus needs be considered here, namely, Eristalis, the larvæ of which have a long anal breathing tube, *i.e.* "rat-tailed," and the adults are commonly called drone flies.

Eristalis tenax, the drone fly (Fig. 153), is a rather large insect, somewhat larger than a honeybee and resembles the drone bee very closely, indeed is commonly referred to as its mimic. The fly deposits its eggs on liquid manure or other filthy liquids in cans, slop jars, privies, etc. The larvæ are known as "rat-tailed larvæ" (Fig. 154); these also occur occasionally in heaps of horse manure.

Fig. 153. — The drone fly, *Eristalis tenax*, whose larvæ are commonly called "rat-tailed larvæ." × 3.5.

Relation to Myiasis. — The frequency with which the "rat-tailed" larvæ occur in liquid excrement must lead to extreme caution in accepting reports that these larvæ have been evacuated with discharges from the bowels. The writer has on several occasions received specimens of "rat-tailed" larvæ which were said to have been evacuated by the "double handful" and that the patient had "steadily improved" thereafter.

There are, however, several cases on record which seem to be incontrovertible, notably the case reported by Hall and Muir,[1] who also bring together all recorded information to date relative to Eristalis and myiasis. The case referred to was that of a boy aged five years "who had been ailing for about ten weeks and who was under medical treatment for indigestion and obstinate constipation for about five weeks of that time. The child was emaciated and anemic. Very striking symptoms were the constant and pronounced twitching of the eyelids and other nervous movements. He gritted his teeth in his

[1] Hall, M. C., and Muir, J. T., 1913. A critical study of a case of myiasis due to Eristalis. Archives of Intern. Med., Vol. II, pp. 193–203.

sleep at times, and made convulsive movements of the limbs. When awake he complained of pain in the limbs and headache. The emaciation seemed to be due to the fact that the boy had for some time vomited almost everything he ate. The breath was very bad, 'worse than rotten eggs' according to his parents. On the basis of the nervous and digestive disturbance and the general debility, a diagnosis of worm infestation was made."

FIG. 154. — The "rat-tailed larva" of *Eristalis tenax*, drone fly. × 2.

With this diagnosis in mind the mother of the boy gave him a dose of a proprietary worm remedy, resulting in the discharge of an object wriggling around vigorously in the feces and urine. The slop jar into which the stool was passed was in regular use and had been previously rinsed with tap water and allowed to dry during the day. The specimen was identified by the authors as one of the "rat-tailed larvæ" measuring 3.2 cm. in length, including the long "tail." A second larva was said to have been discharged the following day. The case is believed by the authors to be probably a genuine case of "gastric myiasis."

After the passage of the larvæ the child is said to have improved in health and became normal, the nervous symptoms and vomiting disappeared.

Three chances for infection were pointed out; namely, first, the eating of "overripe" or probably decaying peaches in which "rat-tailed" larvæ might have occurred; or, secondly, to the drinking of "ditch" water polluted with kitchen refuse, etc.; or, lastly, to stable manure in a neighbor's yard where the child played.

The authors offer the following comment relative to the gastric disturbances:

"A larva supplied with the stigmatic apparatus of *Eristalis* would apparently be fitted for life in a stomach with a small amount of food and plenty of the atmospheric air which is swallowed in eating and drinking and at other times. Such a condition would simulate the normal life conditions fairly closely. That the stomach would not fill to the point where it would drown the larva might be insured by the vomiting, perhaps automatically, the activity of the larva increasing as the stomach filled to where it threatened to cover the rising stigmatic tube, and so setting up an irritation leading to vomiting. The mother states that the child's stomach was extremely intolerant of milk and that drinking milk was promptly followed by vomiting. This suggests that milk, usually taken in long drinks and considerable quantities, quickly threatened the larva with drowning and set up such activity as promptly to cause vomiting."

D. Botflies

Order Diptera, Family Œstridæ

Characteristics of the Œstridæ. — The Œstridæ are described by Williston as follows: "Flies of moderate to rather large size, thick-set, usually more or less pilose. Head large, the lower part more or less swollen. Antennæ short, three-jointed, decumbent, and more or less sunken in the facial groove or grooves; arista bare or plumose. Mouth opening small, the mouth parts sometimes rudimentary, never large. Front broad in both sexes, in the male broader in front. Eyes comparatively small, bare. Ocelli present. Thorax robust, with a distinct transverse suture. Abdomen short, conical or but little elongated; genitalia of the male hidden, the ovipositor sometimes elongated. Legs moderately long, the hind pair sometimes elongated. Tegulæ usually large; sometimes small. Neuration of the wings muscid-like, in most cases the first posterior cell narrowed or closed; anal cell small, usually indistinct; discal cell sometimes absent.

"This family, though of small size comparatively, is of the greatest interest by reason of the habits of the larvæ, all of which that are known are parasitic upon mammals. The adult flies often have rudimentary mouth parts, and devote the whole of their brief existence to the labors of procreation. . . . Parasitism occurs in three principal ways, in the stomach and digestive tubes, in tumors formed by the larvæ under the skin and in the pharyngeal and nasal cavities. With but few exceptions each species is confined to a single species of mammal, and each genus or each group of allied species is parasitic in the same way upon similar animals."

a. Horse Bots

Characteristics. — *Gastrophilus equi* Fabr. is the common horse bot (Fig. 155). This species is described by Osborn, viz., "Adults of this

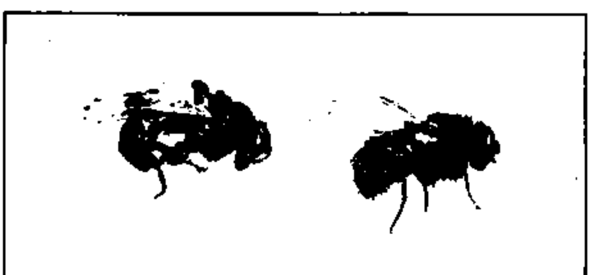

Fig. 155. — The horse botfly, *Gastrophilus equi*. (Female, left; male, right.) × 1.6.

species are about 18 mm. in length, the wings are transparent with dark spots, those near the center forming an irregular transverse band. The body is very hairy, the head brown with whitish front, thorax brown, abdomen brown with three rows of blackish spots, which are subject to considerable variations. In the females the segments are often almost entirely brown with simply a marginal series of yellowish spots, while in the males the abdomen may be almost entirely yellow or very light brown, with brown or dark brown spots very distinct. The males are rarely seen, for while it is one of the most common occurrences to witness the females around the horses depositing their eggs, the males evidently hold aloof. They are readily distinguished by the form of the abdomen, which lacks the two tubular segments at the end, and is provided on the under side of the last segment with a pair of dark brown or black hooks, or clasping organs. Otherwise, except the color of the abdomen, already mentioned, they resemble very closely the females."

FIG. 156. — Eggs of the horse botfly, attached to a hair of the host. × 20.

Life History. — The eggs (Fig. 156), which are light yellow, are attached to the hairs of the forelegs, belly, shoulders and other parts of the body. The female fly may be seen hovering two or three feet away from the horse, and suddenly is seen to dart at the animal, fastening an egg firmly in place. This process is repeated until perhaps several hundred eggs may be attached. The very careful observations of Osborn (and corroborated in the main by the writer) indicate that "the eggs normally require friction and moisture to permit of their hatching and transfer to the horse's mouth, that hatching occurs with difficulty before the tenth day, and most readily after the fourteenth day, and that they lose vitality at a period varying between the twenty-eighth and fortieth days, the bulk not surviving more than four weeks." The newly hatched larva is a very spiny creature (Fig. 157) which readily adheres to moist surfaces, hence must easily adhere to the rough, moist tongue of the horse, passing into the mouth and gradually working its way down the esophagus to the stomach, where it attaches itself to the mucous lining by means of the strong oral hooklets. The stomach wall often becomes so crowded with bots that there is hardly room for a finger to touch the stomach without coming in contact with bots (Fig. 158).

FIG. 157. — Newly emerged larva of the horse botfly. × 60.

The bots remain attached, growing slowly throughout the rest of the summer, autumn and winter, until late spring, when full growth is reached, having molted twice during this time. They are then from 1.5–2 cm. long (Fig. 159). At this time the insects let go, gradually pass out through the intestine with the feces and drop to the ground. Reaching the ground, the bots burrow into loose earth and in a few days pupate. The pupal period varies considerably, depending upon moisture and temperature conditions, but the usual time is from three to five weeks, when the winged flies emerge. Copulation takes place soon, inasmuch as the insects probably partake

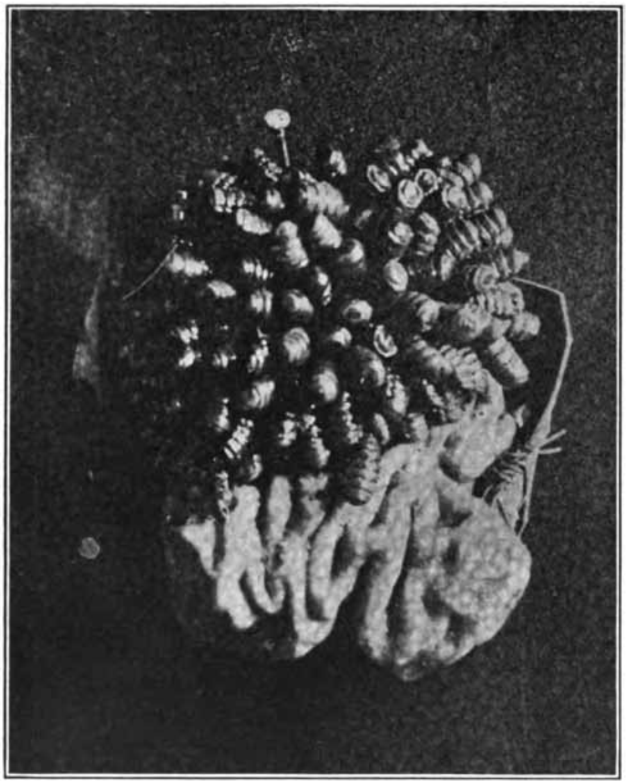

FIG. 158. — Horse bots (*Gastrophilus equi*) attached to inner lining of the stomach of a horse. (Photo by Wherry.) × .75.

of little or no food; egg laying begins again in early summer, and as new individuals emerge continues until autumn.

Pathogenesis. — While a moderate infestation of bots will give no outward indications, a heavy infestation will be indicated by digestive disorders (which may of course be traceable to other causes as well). The discovery of bots in the manure is sufficient evidence. A light infestation is probably of no consequence, — there are indeed some individuals who erroneously maintain that a horse must have at least a few bots in order to be well.

The injury which bots produce is, first, abstraction of nutriment, both from the stomach and its contents; second, obstruction to the food passing from the stomach to the intestine, particularly when the larvæ are in or near the pylorus; third, irritation and injury to the mucous membrane of the stomach due to the penetration of the oral hooklets; fourth, irritation of the intestine, rectum and anus in passage.

Treatment. — Internal remedies are always best and most safely administered by a veterinarian. However, turpentine is commonly used in four-ounce doses, four hours apart, until three or four doses have been administered. It is recommended that the last dose be followed by one ounce of powdered aloes. The use of turpentine is dangerous unless it is given by an experienced person. Washburn[1] states that carbon bisulphide has been used in Italy with marked success. Six gelatine capsules, each containing 15 grains of CS_2, were given to two horses at intervals of two hours. During the four following days the first horse passed 497 bots, the second in five days, 571 bots. Another party gave one horse 32 grains in five hours, and the animal passed 203 bots. Horses so treated should be carefully watched, and if any bad effects appear, treatment should be stopped.

Fig. 159. — Larva of *Gastrophilus equi*, the horse bot. × 4.

Prevention. — The object in view is to prevent the botfly larvæ from gaining entrance to the mouth of the horse, hence control methods involve the egg. The first method that presents itself is to prevent the fly from depositing its eggs on the horse. This can be done by keeping the animals stabled during the day, giving them free range at night.

A second method involves the destruction or removal of the eggs from the horse. Touching the eggs lightly with kerosene, benzine or gasoline proves effective. The eggs are easily removed with a sharp razor or clippers, in which case treatment is unnecessary.

Based on our knowledge of the egg stage it would seem that very few bots would reach the stomach of the horse if the animal is treated as above at least once every two weeks.

If internal remedies are administered and the bots are full grown or nearly so, it is safer to treat the manure copiously with kerosene, carbolic acid or sheep dip in order to destroy the larvæ to prevent pupation and emergence of the flies.

Other Species of Horse Bots.—*Gastrophilus hæmorrhoidalis* Linn. is

[1] Washburn, F. L., 1905 (*loc. cit.*).

the red-tailed bot. This species is about 1.5 cm. in length with an orange-red-tipped abdomen. "The thorax is olive-gray and hairy, with a black band behind the suture. The base of the abdomen is whitish and the middle blackish, in strange contrast with the orange-red of the end." The eggs of this species are dark brown to nearly black and are deposited on the long hairs of the horse's lip. The incubation period is very much shorter than in *G. equi*. The larvæ find their way into the mouth on food or with the tongue in licking, and eventually reach the stomach. The fully grown larvæ are from 12 to 15 mm. long. Law describes the larvæ, viz.: "The spines are arranged in a double row on each ring, but on the dorsal aspect they are absent in the middle of the ninth ring, while on the tenth and eleventh there are none. The larvæ pass the winter mostly attached in groups in the left sac of the stomach, but also in the right sac, and duodenum, and exceptionally in the pharynx."

"When mature and passing out through the intestines they often hook themselves for a time to the rectal mucosa, where they cause considerable irritation and rubbing of the tail. They also pass through the anus independently of defecation, and hook themselves to the skin round its outer margin, causing rubbing and switching of the tail, and a stiff awkward gait. This habit, with that of laying the eggs on the lips and jaw, and of hooking on the delicate mucosæ of the pharynx, right gastric sac and duodenum, renders this one of the most injurious of the Œstridæ" (Osborn).

The pupal stage is entered soon after the bot drops to the ground and buries itself, and lasts from four to six weeks and over. The flies occur from early summer to late autumn.

Gastrophilus nasalis Linn. is the chin fly, which measures about 1 cm. in length. It is "densely hairy, with the thorax yellowish red or rust colored. The abdomen is either whitish at the base, with the middle black and the apex yellowish brown and hairy, or the base is whitish and all the rest brown; or the middle is black; with the base and apex whitish, with grayish hairs. The wings are unspotted" (Verrill).

The white eggs are deposited on the lips or around the nostrils. The larvæ are "furnished with a row of spines on each ring from the second to the ninth on the dorsal surface, and as far as the tenth on the ventral. There is an unarmed part in the center of the eighth and ninth rings on the dorsal surface. It spends the winter attached to the mucosa of the commencement of the duodenum, usually in clusters, and is rarely found in the stomach. In passing out it shows no tendency to hook itself to other parts of the intestine or the anus" (Law).

The remainder of the life history is as in other species already described.

Gastrophilus pecorum Fabr. is about the same size as *G. equi*. In color it is yellowish brown to nearly black. The wings are brownish and clouded. In egg deposition, life history and habits this species resembles *G. equi* very closely. It is said to be rare or absent in the United States.

b. Ox Warbles

Characteristics. — *Hypoderma lineata* Villers is the common ox warble fly (Fig. 160), also known as the "heel fly," which, together with a less prevalent species, *H. bovis* De G., is responsible for the warble or grub in cattle. This species is described as follows: "Length, 13 mm. (15 mm. with ovipositor extended); general color, black; body more or less clothed with yellowish white, reddish and brownish black hairs. The front, sides, and back of the head, the sides of the thorax, a band across the base of the scutellum, and the basal segment of the abdomen are covered with long yellowish white, almost white, hairs. The head above, central thoracic region, including prothorax and mesothorax, middle segments of the abdomen above, and legs, clothed with brownish black hairs, which on the head and thorax are more or less intermixed with whitish hairs. The covering of hairs is shorter and scantier on the head and thorax, and the tip of the scutellum and following parts of the thorax, together with four prominent lines on the thorax, smooth and highly polished. The hairs of the terminal segments of the abdomen are reddish orange, which color also predominates on the hind tibiæ."

Fig. 160. — The ox warble fly, *Hypoderma lineata*. × 2.6.

Life History and Habits. — The female deposits her eggs on the feet, legs, flanks, belly and other parts of the body. The eggs are white, about 1 mm. long, and are securely attached in rows of six, more or less, on a single hair. Deposition occurs from early summer to late autumn. The larvæ hatch in a week more or less, protruding the body from the egg or crawling out and clinging to the hairs of the host, when they are licked off with the tongue, pass into the mouth, thence into the esophagus, and often into the paunch. Once in the esophagus or paunch the larvæ burrow, finding their way into the tissue between the mucous membrane and the muscular coat of these organs. In this region the smooth yellowish white larvæ remain for the rest of the summer and autumn and grow to be from 12 to 15 mm. in length. During the late autumn and winter the still smooth larvæ begin to penetrate the muscular coat of the esophagus, entering the connective tissue of the abdominal cavity and dorsal muscles, continuing their migration toward the back of the host. The large warble (*Hypoderma bovis*) is said to often enter the spinal canal through the intervertebral foramina, remaining there for two or three months and leaving this location by the same path which was followed on entering, and soon find their way to their ultimate position in the host in the subcutaneous connective tissue beneath the skin of the back. Larvæ are also known to enter the skin directly.

About the latter part of December (the writer has observed them about Christmas time) there appear the small swellings along the back (near the spinal column) of the cattle. These lumps it will be noted change in position from day to day, appearing on the shoulders, sides and rump as well. Soon the lumps become stationary and there appears a small opening in the middle of the elevated area through which the grub receives oxygen, having its posterior end close to this hole. The skin is again shed (the third and last molt) and the larva now appears as a thick heavy set spiny maggot about 25 cm. in length (Fig. 161). The tumor increases to the size of a walnut, the aperture becomes larger and in early to late spring the grub crawls out, falls to the ground, burrows into loose earth and in a day or two pupates. The pupa is about 2 cm. long, dark brown to black in color. The winged insect emerges from the pupa case in from three to five weeks and over.

Fig. 161. — Larva or grub of the ox warble fly, *Hypoderma lineata*. × 1.3.

Hypoderma bovis De G. is commonly called the European or larger warble fly. This species is now known to occur in British Columbia. In Europe, *H. Bovis* predominates over *H. lineata*. It is about 15 mm. in length against 13 mm. in the latter. Both species are hairy, resembling bees, the ground color is black with long hairs on the front, sides and back of the head, sides of thorax and base of abdomen. In *H. bovis* these hairs are greenish yellow. The tip of the abdomen in both species is reddish yellow, deeper and more hairy in *H. bovis*.

The life history of the two species is very similar. The larvæ are different enough to distinguish them readily. The fully grown larva of *H. bovis* is longer, 27–28 mm., *H. lineata* about 25 mm. The two species are distinguished on the basis of their spiny armature. In *H. lineata* each segment of the larva is provided with spines except the last, the ring upon which the stigmata are located, while in *H. bovis* all except the last *two* are armored.

Injury Done. — The injury done by the warbles is first that of *irritation* caused by their migrations in the body of the animal and later in their emergence from beneath the skin; secondly, the escape of the larva from the tumor leaves an open, running wound which persists for a long time and is attractive to screw worm flies and other tormenting insects. The direct pathogenesis is of minor importance, however, in the face of the economic loss produced by this insect.

Economic Losses. — The economic losses produced are *first*, reduction in milk secretion, which is estimated at from 10 to 20 per cent of the normal yield; *second*, loss of flesh due to the wild endeavor of the animals to escape from the flies and the irritating larvæ (which is pointed out by Holstein, viz.: "A cow quietly grazing will suddenly spring forward, throw up her tail, and make for the nearest water at a headlong gait. Seemingly deprived at the moment of every instinct except the

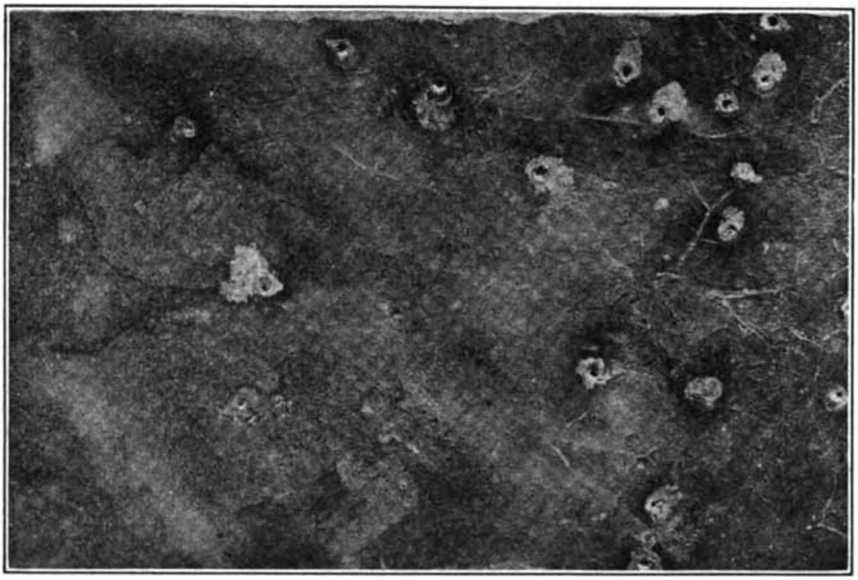

Fig. 162. — A piece of sole leather (Grubby Jumbo), 21 × 31.5 cm. showing work of ox warble. × 3.

desire to escape, she will rush over a high bluff on the way, often being killed by the fall. This, with miring in water holes and the fact that cattle are prevented from feeding, causes the loss"); *third*, depreciation of the value of the carcass as flesh, which becomes greenish yellow and jelly-like in appearance at the points where the grubs are located, and is not fit for consumption; *fourth*, injury produced to the hide which becomes 'grubby,' full of holes where the grubs have emerged (Fig. 162).

The following is quoted from *Tanners' Work* for October, 1913: "The case is recorded by Boas of Denmark of a cow which remained in poor condition and gave 33 pounds of milk per day. Forty-six grubs were extracted from this animal and eight days later she was giving 44 pounds of milk per day, continued to do so most of the summer and was in good flesh and condition in the fall. In this case the loss of milk due to the grub infestation was 25 per cent. The loss in flesh on account of grubs has been variously estimated at from \$1.00 to \$5.00 or more per head. If we assume that 25 per cent of all of the cattle in the United States are more or less infested with grubs, a quite conservative estimate, 50 per cent probably being nearer the actual percentage, the loss in flesh on account of grubs amounts to from $15,000,000 to $75,000,000 a year, the total number of cattle in the United States being calculated as approximately 60,000,000. If we also assume that infested milch cows lose 10 per cent in milk production and that 25 per cent of the 20,000,000 milch cows in the United States are affected, there should be added to the account a loss of not less than $30,000,000 per year.

"As to the loss in hides it is stated by European tanners that a grubby hide is, on the average, less in value by one third than a perfect hide, but for this country, I have no definite information other than that grubby hides in the green state are commonly valued at 1 cent a pound less than perfect hides. On this basis the depreciation in value of a hide of average weight of 65 pounds if grub-infested, would be 65 cents and the depreciation in the value of the estimated 15,000,000 grubby cattle of the United States so far as their hides are concerned thus amounts to $9,750,000. It is, however, quite probable that the actual loss in the value of hides when made into leather is much greater than this.

"Without including the loss on account of the direct damage to beef carcasses from the presence of grubs, we may, on the basis of the foregoing, estimate the total loss from grubs in the United States in round numbers at from $55,000,000 to $120,000,000 per year."

Treatment. — The tumors in which the grubs occur may be treated with kerosene, benzine, turpentine or carbolic acid, a few drops of which are introduced into the opening by means of a machinist's oiler, or merely smeared over the surface. Ointment of sulphur and vaseline are also serviceable. These remedies are objectionable inasmuch as the grubs are not eliminated, dying within the tumor where they must be slowly absorbed; serious abscesses may result.

The grubs may also be destroyed *in situ* with a sharp scalpel or a hot needle, but here again the same objection as above is encountered.

A better method is to remove the grubs bodily, which can easily be done by squeezing them out if the grubs are about ready to leave the tumor. If not easily squeezed out, a forceps with slender blades may be introduced into the opening, the grub grasped and eliminated. In some cases the use of a lancet may be needed to widen the opening in the tumor.

After removal the grubs must be destroyed to prevent further metamorphosis, and the wound should be treated with a carbolated salve.

Prevention. — Owing to the fact that the eggs hatch very soon after deposition, treatment with kerosene, benzine or gasoline would have to be given as soon as the eggs are noticed. This treatment is not particularly practical but is not to be disregarded.

Removal of the grubs or treatment of the same prevents the completion of metamorphosis and hence results in the reduction of the number of adult flies for the next season.

Associations for the eradication of grubs have been formed in Europe, which cope with the problem through educational methods. In some districts a bounty is offered from ½ cent to ⅝ cent per grub. Their efforts have given very good results. No practical method of eradication in range animals is at hand, but certainly there is no reason why with proper coöperation and systematic effort this evil could not be controlled where only smaller herds are concerned, thus actually saving large sums of money to the stock raiser and dairyman.

c. *Head Maggot of Sheep*

Characteristics. — *Oestrus ovis* Linn. is the botfly of sheep, or the sheep gadfly, the larva of which is the common head maggot of these animals. 'Grub-in-the-head,' 'false gid' and 'staggers' are common designations.

FIG. 163. — Head maggot fly (*Œstrus ovis*) of sheep. × 4.

The fly (Fig. 163) is somewhat larger than the common house fly, dull yellow or brownish in color and hairy. The abdomen is variegated with brown and straw yellow, the feet are brown. It is further described by Osborn as follows: "The under side of the head is puffed out and white. The antennæ are extremely small and spring from two lobes which are sunk into a cavity at the anterior and under part of the head. The eyes are purplish brown, and three small eyelets are distinctly visible on the top of the head. It has no mouth and cannot, therefore, take any nourishment. The wings are transparent and extend beyond the body, and the winglets (calypteres) which are quite large and white, cover entirely the poisers. It is quite lazy, and, except when attempting to deposit its eggs, the wings are seldom used."

Life History. — The head maggot fly deposits living young from early summer to autumn in the nostrils of sheep and goats. These at once begin to migrate up the nasal passages, working their way up into the nasal sinuses often as far as the base of the horns in rams and attach themselves to the mucous membranes. Here numbers of these whitish grubs may be found wedged in closely in various conditions of development (see Fig. 167). The posterior ends which are unattached present conspicuous spiracles. The grubs (Fig. 164) reach full growth with a length of from 25 to 30 mm. by the following spring, — a larval period of from eight to ten months. At the end of this time they let go, wriggling their way out of the nostrils, fall to the ground, bury themselves in the earth and pupate in a few hours. The pupal period lasts from three to six weeks and over.

Symptoms. — In the presence of the fly the sheep are very much excited, shake the head, rush with their noses between their fellows,

Fig. 164. — Head maggot (*Œstrus ovis*) of sheep. × 2.5.

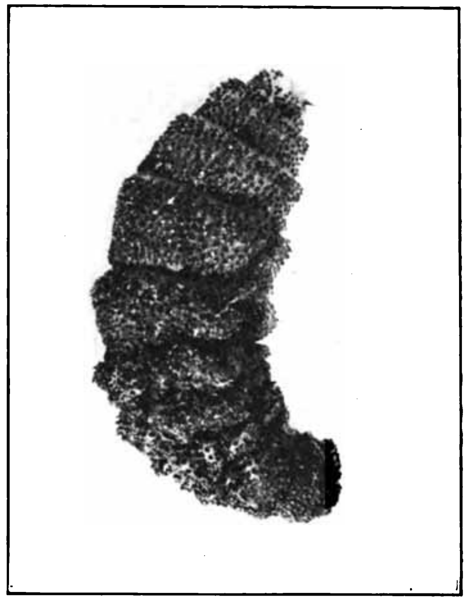

Fig. 165. — The larva of a rabbit botfly, *Cuterebra sp.* × 3.

push their noses into the dust, snort and otherwise indicate that they are trying to escape something that persists in entering the nostrils. Once infected there is a purulent discharge from the nostrils, vigorous shaking of the head, and perhaps occasional discharge of a maggot, loss of appetite, grating of the teeth, and when the animal walks the fore feet are lifted in a pawing movement.

The great majority of the cases do not result fatally, but death often results in a week more or less after the appearance of aggravated symptoms.

Grub-in-the-head is distinguished from "gid" (caused by a larval tapeworm, *Cœnurus cerebralis* = *Multiceps multiceps*) in that the former is always associated with purulent discharges from the nostrils, absent in the latter, and that the symptoms of the former appear during the summer, and that the latter occurs ordinarily in lambs and yearlings only (Law). There is no undue sneezing or rubbing of the nose in gid.

Treatment. — Materials such as snuff, pepper, etc., may be introduced into the nostrils or sprinkled among the flock, to induce violent sneezing, which causes the expulsion of many of the larger grubs. Law recommends the injection of benzine, lifting the sheep's nose somewhat and pouring into the nostrils a teaspoonful of the remedy for each nostril. The lower nostril into which the benzine is poured is held shut for thirty seconds; the other side is then turned and the treatment repeated. The application is repeated daily or oftener until the maggots are all expelled.

Prevention. — The use of "salt logs" in sheep pastures is made by some sheep raisers. These logs are made by boring two-inch holes at intervals of about six inches along the length on top. Salt is placed into these holes, which are kept about half full, and in turn the edges of the holes are repeatedly smeared with pine tar, or other repellent material. In endeavoring to reach the salt the sheep involuntarily smears its nose with the substance, which protects it to a large extent against the head maggot fly.

d. Bots in Rodents

Bots in Rodents. — Various species of rodents, notably rabbits, rats and squirrels are infested at times with bots or perhaps we had better say, warbles (Fig. 165). Rabbits, both wild and tame, are commonly affected by *Cuterebra cuniculi* Clark, and probably other species. *C. cuniculi* is a large black and white bumblebee-like fly (Fig. 166). Just where the eggs are deposited and how the grubs reach their position under the skin is still unknown. After leaving the body of the host the larvæ pupate in three or four days, remaining in the pupal stage often for a considerable period; one case observed by the writer pupated October 25, 1912, and emerged August 12, 1913.

FIG. 166. — A rabbit botfly, *Cuterebra sp.* × 1.3.

The emasculating bot (*Cuterebra emasculator* Fitch) of squirrels is found in the grub stage in the scrotum of squirrels of several species.

e. Head Maggot of Deer

Head Maggot of Deer. — The black-tailed deer (*Odocoileus columbianus*) and probably other species as well are commonly affected with head maggots, a species of the genus *Cephenomyia*. The attached figure (Fig. 167) illustrates the fact that the larvæ crowd into the sinuses and that there are all sizes, from very young to fully grown, present at the same time.

f. Warbles in Humans

Warbles in Humans. — Humans, notably in Central and South America, Mexico and other tropical countries, are rather commonly affected with warbles traceable to one of several species of Œstrids,

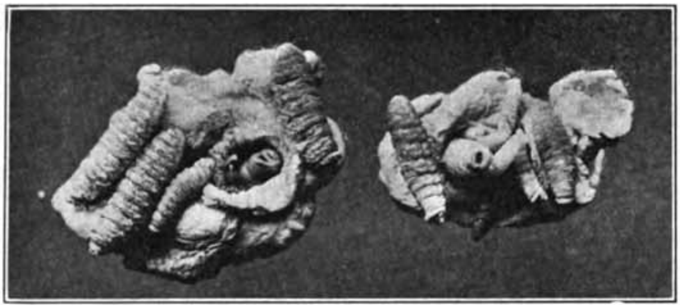

FIG. 167. — Head maggots, larvæ of *Cephenomyia sp.* attached to tissue in nasal sinuses of the deer. × .6.

notably *Dermatobia hominis* Gmelin = *Dermatobia noxialis* Guodot = *Dermatobia cyaniventris* MacQ., *Hypoderma lineata*, Vill., and *H. bovis*, DeG.

Dermatobia hominis Gmelin[1] is commonly found in Central and South America and Mexico. The larva is known in its early stage as *Ver macaque* and in its later stages as *torcel* or *berne*. The fly measures from 14 to 16 mm. in length, is entirely brown in color. This fly parasitizes a large number of species of mammals and even birds. It has been found in cattle, pigs, dogs, mules, monkeys, man and various wild animals. In man the larva " has been reported from various regions of the body, mainly head, arm, back, abdomen, scrotum, buttocks, thigh and axilla."

Whether the fly introduces the egg under the skin of its host by means of the ovipositor is unknown but in certain recorded cases there is a history of a sting. According to some authors the larval period requires about three months when the insect leaves the flesh, drops to the ground and pupates, the pupal period requiring about six weeks.

Pathogenesis. — The following is quoted from Ward (*loc. cit.*): " Dr. Brick was stung by some insect while bathing and the larva was extracted after about six weeks. It gave rise to excruciating pain at intervals, owing, as he inferred even before the determination of the cause, to 'something alive beneath the skin.' It was at first 'a considerable tumefaction over the tibia, which had the appearance of an ordinary boil (phlegmon); in the center there was a small black speck.'

[1] Ward, H. B., 1903. On the Development of *Dermatobia hominis*. Mark Anniversary Volume, Article XXV, pp. 483–512. (Includes a discussion of synonymy of species).

The tumor began to discharge at about four weeks, and was so serious that he was 'scarcely able to walk.' Scarifying the tumor yielded no results, and finally poulticing with cigar ashes and rum for five days resulted in the extraction of the larva dead. Dr. Brick records that 'it had traveled on the periosteum along the tibia for at least two inches.' While other authors hold very generally that the larva always inhabits a fixed spot in the subcutaneous tissues, I do not find that any one has referred to this record of migration made by a most competent observer."

The following observation made by Miller (Journ. Amer. Med. Assoc., Vol. LV, pp. 1978–1979) throws more light on the matter of migration, although in this case the grub was *Hypoderma lineata*. "In December, 1907, the boy noticed a small round lump just below the left knee; this lump was slightly red and very tender, especially at night. About two days later the lump had disappeared from its original position and was found some three inches above the knee; the following day it was still higher in the thigh, and during successive days it appeared at different points along a course up the abdomen, under the axilla, over the scapula, up the right side of the neck, irregularly about the scalp, finally passing back of the ear and to the submental region, which it reached about two months after its first appearance; there it remained stationary. The extracted larva was identified by Doctor Stiles as *Hypoderma lineata*."

Identification of Myiasis-producing Larvæ. — The value of a simple method for the identification and classification of dipterous larvæ involved in myiasis is no doubt evident to the student of this subject. Instances are few in which the larvæ can be reared to the adult condition, when identification could of course be readily made. Authorities are now for the most part agreed that the *posterior spiracles* afford the most useful diagnostic characters, since these, while differing consistently in position, form and structure for the genera and species, show little or no variation within the species except in a few species in the very early stage immediately after hatching.

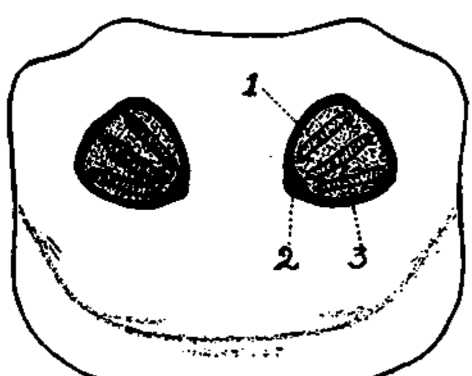

FIG. 168. — Posterior view (stigmal field) of the larva of *Calliphora vomitoria*, showing stigmal plates. (1) ring; (2) button; (3) slit-like spiracles.

To prepare the specimen for study it is necessary to first remove by means of a sharp razor the extreme posterior end (usually the broader), — a very thin section is needed. This section is then boiled until quite clear in a 2 per cent solution of potassium hydroxide (KOH), or by soaking in xylol for a few hours, after which it is prepared in the usual way for microscopic study.

It will be seen (Fig. 168) that there are two *stigmal plates* more or less separated from each other, within which are situated the *spiracles*, one to three in number, either slit-like, sinuous or more or less circular. There may or may not be present a " button," *i.e.* a prominence located at the narrower segment of the ring or periphery of the stigmal plate; the " button " may or may not be present in the species possessing slit-like spiracles.

In using the posterior spiracles as diagnostic characters, the above conditions are considered, *i.e.* (1) *diameter* of the stigmal plate, the space occupied by one stigmal plate on a line drawn through the center of both; (2) *length*, when slits are absent, the space occupied by a plate on a line drawn dorsoventrally through the center of the plate; or, when slits are present, the space occupied by a plate along a line drawn from the lower edge of button (or space if button is absent) through the longest slit (middle slit) to the margin of the plate; (3) *width*, along a line drawn at the middle of the plate at right angles to the *length* line; (4) distance between the plates; (5) general form of the plates; (6) shape of spiracles; (7) presence or absence of *button*; (8) general structure of plate.

The following key,[1] while still somewhat unsatisfactory, serves to classify the principal families of Diptera which include genera and species relating to myiasis. In this key the entire larva is needed for identification.

KEY TO THE IDENTIFICATION OF LARVÆ OF THE DIPTEROUS FAMILIES AND CERTAIN SUBGROUPS WHICH INCLUDE GENERA AND SPECIES RELATING TO MYIASIS

I. (*a*) Body cylindrical, tapering anteriorly II

(*b*) Body robust, ovate, cylindrical, rounded at the ends, slightly depressed . . . . *Œstridæ*
e.g. *Gastrophilus equi*, *Œstrus ovis*, *Hypoderma lineata*

(*c*) Body elliptical, much depressed dorsoventrally; segments provided with long spiny processes . . . . *Homalomyia*
(sub-group of Anthomyidæ)
e.g. *Fannia* (*Homalomyia*) *canicularis*, *Fannia* (*Homalomyia*) *scalaris*

(*d*) Body with long tail-like process . . . . *Eristalis*
e.g. *Eristalis tenax*

II. (*a*) With one anterior hooklet; stigmal field slightly depressed; area surrounding stigmal field usually devoid of tubercles, which if present

[1] The author is indebted to Mr. I. M. Isaacs for much careful and tedious work in the construction of the above key.

are small and insignificant; spinose areas only on ventral surfaces of segments III

(b) With two anterior hooklets IV

III. (a) Posterior spiracles with sinuous slits . . *Muscidæ* (except Muscina subgroup)
e.g. *Musca domestica, Stomoxys calcitrans, Hæmatobia serrata*

(b) Posterior spiracles with three short straight slits in each plate; few faint tubercles around stigmal field . . . . *Muscina* subgroup
e.g. *Muscina stabulans*

IV. (a) Spinose areas completely surrounding segment and occasionally supplementary pads on the lateral surfaces . . . . (1) or (2)

(1) Stigmal field depressed and surrounded by prominent tubercles; posterior spiracles with three distinct slits in each plate; plates directed more or less toward each other . . . . *Sarcophagidæ*
e.g. *Calliphora vomitoria, Calliphora erythrocephala, Lucilia cæsar, Lucilia sericata, Chrysomyia macellaria, Auchmeromyia luteola*

(2) Very small (not over 4–5 mm.); anterior spiracles with few, but comparatively long lobes; posterior spiracles on end of two cylindrical processes extending posteriorly from the dorsal part of the tips of the body . . . . *Drosophilidæ*
e.g. *Drosophila ampelophila*

(b) Spinose areas on ventral and lateral surfaces; stigmal field slightly depressed and surrounded by short fleshy tubercles . . . . . . *Anthomyidæ* (except Homalomyia subgroup)
e.g. *Anthomyia radicum, Phorbia brassicæ*

(c) Body segments with spinose areas only on ventral surfaces; anterior spiracles with a large number (20 ±) of lobes; slightly depressed or flat stigmal field; no tubercles; posterior spiracles with three short almost parallel slits, those of one plate pointing toward those of the other; plates lacking brown chitinous borders; anal tubercles prominent, rounded and flattened . . . . *Trypetidæ*
e.g. *Ceratitis capitata, Dacus oleæ*

The following species may be more or less easily identified:

Family Muscidæ

Musca domestica, Linn. Stigmal field usually slightly concave and the surrounding area devoid of distinct tubercles; stigmal plates prominent, somewhat longer than wide, D-shaped, flat sides facing, about one third diameter apart; spiracles apparently three in number and sinuous; button absent in first stage on hatching; button present thereafter, large and very dark, embedded near the center of the flattened side of stigmal plate; ring heavy and dark. (Larva of house fly.)

Stomoxys calcitrans, Linn. The stigmal field is slightly convex and is in the dorsal half of the posterior end. There are no tubercles outlining the field. The species can easily be recognized not only by the size and shape of the spiracles but by the distance between the two plates, there being from two and a half to three diameters between them. The plates themselves are small, triangular in shape and black in color. In this species each of the slits is surrounded by light areas which appear in each corner of the triangular plates. (Larva of biting stable fly.)

Hæmatobia serrata R. Desv. The stigmal field of *H. serrata* is neither depressed nor outlined by tubercles. In shape the stigmal plates are D-shaped, as are those of *M. domestica,* but are proportionately much narrower. They are very dark in appearance, due to the fact that the black chitinous edges are joined to the comparatively large black button, by three wide chitinous stripes. Portions of the sinuous slits may be seen in the small clear spaces left between the stripes. The three-part division of the surface is very similar to that found in the spiracles of *Stomoxys calcitrans.* The plates are about one fourth of their diameters apart and therefore close together compared to *Musca domestica.* In some cases there is a tendency toward a slightly triangular shape in the spiracles. (Larva of horn fly.)

Muscina stabulans Fallen. The stigmal field is not depressed and faint tubercles may be seen dorsal to it. The spiracles are fairly prominent, almost round in shape with the inner border slightly flattened, black, with three short slits in each plate pointing toward those of the opposite plate, and from one third to one half a diameter apart. (Larva of non-biting stable fly.)

Family Sarcophagidæ

Calliphora erythrocephala Mg. The stigmal field is slightly depressed. The stigmal plates are small and about one diameter apart. The slits in each plate converge more than do those of the other species mentioned and point almost directly toward those of the opposite plate. In the first period the plates are about as long as they are wide, occasionally being slightly wider, there being no button. In the second period they are slightly longer than they are wide, there being a prominent, bullet-shaped button, and the ring is dark and very heavy. (Bluebottle fly larva.)

Lucilia cæsar Linn. The stigmal field is slightly depressed and is outlined by somewhat fleshy tubercles. The stigmal plates themselves are longer than they are wide and are considerably larger than are those of *C. erythrocephala.* A well-developed button is present. The ring is thin and delicate. The slits, although directed more or less toward those of the opposite plate, point more toward the ventral surface than do those of *C. erythrocephala* and do not converge as much. (Larva of the greenbottle fly.)

Lucilia sericata Mg. The stigmal field is well depressed and is outlined by tubercles more or less conical but not very sharp. The stigmal plates are comparatively large in both the first and second period.

In the first period the plates are wider than they are long and are close together, being only about one eighth of a diameter apart. The slits are long and rather narrow, pointing ventrally, those of one plate being directed in some measure toward those of the opposite plate. There is no button.

In the second period the plates are proportionately longer than in the first period and they are about one fourth of a diameter apart. The slits also are wider in proportion and although still directed ventrally they point slightly more toward those of the opposite plate. Care must be taken as to the exact meaning of length and width in this species. (Larva of sheep maggot fly.)

Chrysomyia macellaria Fabr. The stigmal field is a very deep depression of the dorsal half of the posterior end. The depression is so deep that the lip-like edges of the last segment almost conceal the spiracles. Outlining the stigmal field are small but sharp tubercles. The stigmal plates are fairly large and are about as long as they are wide. There is no button. In the first period the plates are about one fourth of a diameter apart, while in the second period they are a little over one half of a diameter apart. The slits point ventrally, those of one plate being directed in some measure toward those of the opposite plate. (Larva of Texas screw worm fly.)

Family Anthomyidæ

Fannia (Homalomyia) canicularis Linn. Each segment is provided with long, bristly, sharp, spiny processes. The posterior spiracles are situated on the anterior part of the last segment, they are raised, three-lobed processes. The lobes are distinct and can easily be seen. The larvæ are about 8 mm. in length when fully grown. (Larva of the lesser house fly.)

Fannia (Homalomyia) scalaris Fabr. The processes on each segment are feathery rather than sharp or spiny and are not quite as long as the processes of *F. canicularis*. The posterior spiracles also differ in the two species, the lobes not being as well marked in *F. scalaris*. The larvæ are from 7 to 8 mm. in length when fully grown. The feathery appearance of the processes on the segments as compared to the spiny condition in *F. canicularis* is, however, most useful in distinguishing the two species. (Larva of the latrine fly.)

Family Trypetidæ

Ceratitis capitata Wied. The stigmal field as a whole is not depressed nor is it outlined by tubercles, but occasionally each stigmal plate appears to be situated in a slight depression of its own. The plates are fairly prominent and are about twice as wide as they are long. In accordance with the group character, there is no visible chitinous edging outlining the plates. The slits of each spiracle are almost parallel and point directly toward those of the opposite plate. The spiracles differ from those of *D. oleæ* only in the distance separating the two plates, they being about one diameter apart. (Larva of Mediterranean fruit fly.)

Dacus oleæ Meig. The appearance of the stigmal field and posterior spiracles of this species are very much like those of the previous species, except for the fact that the plates are from one and a half to two diameters apart. As in *C. capitata* there is no chitinous border outlining the spiracles, which are about twice as long as they are wide. The short straight slits of one plate point almost directly toward those of the opposite plate. (Larva of olive fly.)

Family Œstridæ

Gastrophilus equi Fabr. One of the smallest of the Œstridæ. A full-sized larva is about 17 mm. in length and 8 mm. in width at its widest part. It is compressed, in some measure, dorsoventrally. It is wide and thick near the posterior end and tapers almost to a point anteriorly. The spines surrounding each segment are large and sharp. The two anterior hooks are prominent.

The stigmal field of this species is drawn well into the anterior portion of the last segment and is completely covered and protected by a prolongation of the outer edges of this segment.

On a hard, chitinous background are six long, large, bent slits, bilaterally placed, three on either side of a small diamond-shaped hollow. (The larva of the horse botfly.)

Hypoderma lineata De G. is a large and fleshy grub and when fully developed is about 25 mm. in length and 11 mm. in width at its widest part. It is considerably depressed dorsoventrally and the segments are spinose although the large separate spines found in *Gastrophilus equi* are not present.

The stigmal field is depressed but is not covered by any prolongation of the edges of the last segment. The spiracles are large, close together and grossly granular in appearance, in some cases being more or less furrowed. A good-sized button is embedded near the inner border of each plate and in many cases a clear ungranulated stripe is found on the chitinous background between the button and the inner border. The plates usually appear to be dark brown with the button a little lighter in color. (The ox warble.)

Œstrus ovis Linn., when fully developed, is about 28 mm. in length and 8–10 mm. in width. It is, therefore, longer and narrower than *H. lineata*, a condition which gives it a more rounded appearance. The dorsoventral compression, however, is noticeable. The segments are spinose.

The stigmal field is depressed. The plates are roughly round, with the inner borders flattened. The plates are very dark, finely granular in appearance with a somewhat indistinct button in the center of each plate. (The sheep head maggot.)

CHAPTER XVII

FLEAS AND LOUSE FLIES

A. Fleas

Order Siphonaptera

Structural Characteristics. — Fleas are laterally compressed, wingless, highly chitinous, mostly leaping insects of small size, inhabiting by preference certain warm-blooded hosts and are blood-sucking in both sexes. In size the common fleas vary from 1.5 to 4 mm. in length, according to the species, though there is comparatively little variation within a given species. The males are as a rule somewhat, often considerably, smaller than the females. Nearly all fleas have the ability to leap, though the Chigoe fleas, especially the females, are more or less sessile.

The posterior edges of the abdominal segments are provided with backward-extending spines, which hinder backward motion through the hair of the host. The piercing mouth parts (Figs. 169–170) of the adult fleas are flattened, blade-like structures consisting of a pair of triangular maxillæ with jointed palpi between which are located the organs of the proboscis proper, *i.e.* an outer pair of structures comprising the labium which ensheaths loosely the inner, more slender stylets, — a pair of mandibles with serrate edges, and a smooth labrum (hypopharynx?). On the small head are also located the sunken antennæ with annulated knobs, and the inconspicuous simple eyes (absent in some species). In some species of fleas the head is provided with rows of spines (Fig. 171), the *ctenidia,* a valuable characteristic in classification; the ctenidia may be located just above the mouth parts and are then said to be *oral,* or may be situated back of the head and are then thoracic or *pronotal* (both sets may be present).

Fig. 169. — Photomicrograph of the mouth parts of a flea, — front view. (For identification of parts see next figure.)

The legs consist of five joints; viz. the *coxa* (the joint nearest the body), the *trochanter*, a very small segment between the coxa and the *femur*, the *tibia* (strongly spined), and the five-jointed *tarsus* terminating in a pair of *ungues* or claws (Fig. 171).

Life History. — The eggs of the flea (Fig. 172*a*) are large (.5 mm. long), glistening white, blunt at both ends. Comparatively few eggs are deposited, the observed range being from 3 to 18. Most species

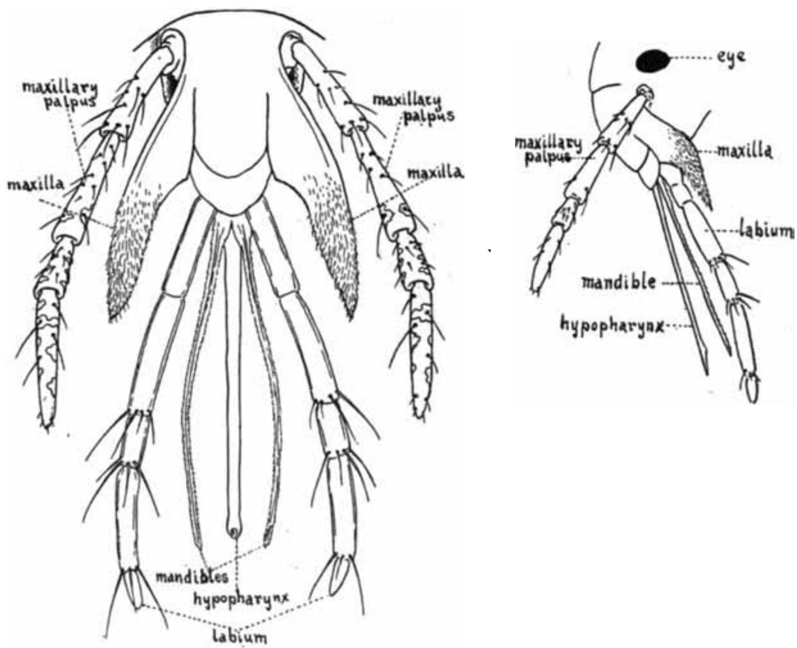

FIG. 170. — Showing mouth parts of a flea. A, front view; B, side view.

deposit dry eggs and hence they do not become attached to the hairs of the host even though oviposition has taken place there. There is every reason to believe that some species of fleas seldom or never deposit their eggs among the hairs of the host, preferring the loose earth, excrement, dust, etc. Captured fleas will readily oviposit in glass vials or other receptacles. If deposited on a dog, for example, the dry eggs fall off readily when the animal stretches and shakes itself; thus myriads of eggs may be found on the sleeping mat of a flea-infested animal.

The length of time required for the egg stage depends largely if not wholly on temperature. High mean temperature from 35° C. to 37° C. inhibits development, which may account for the fact that the eggs do not hatch well on the host. At a temperature of from 17° C. to 23° C. Mitzmain[1] found that the egg stage lasted from seven to nine days; at from

[1] Mitzmain, M. B., 1910. General observations on the bionomics of the rodent and human fleas. U. S. Public Health Service Bull. 38.

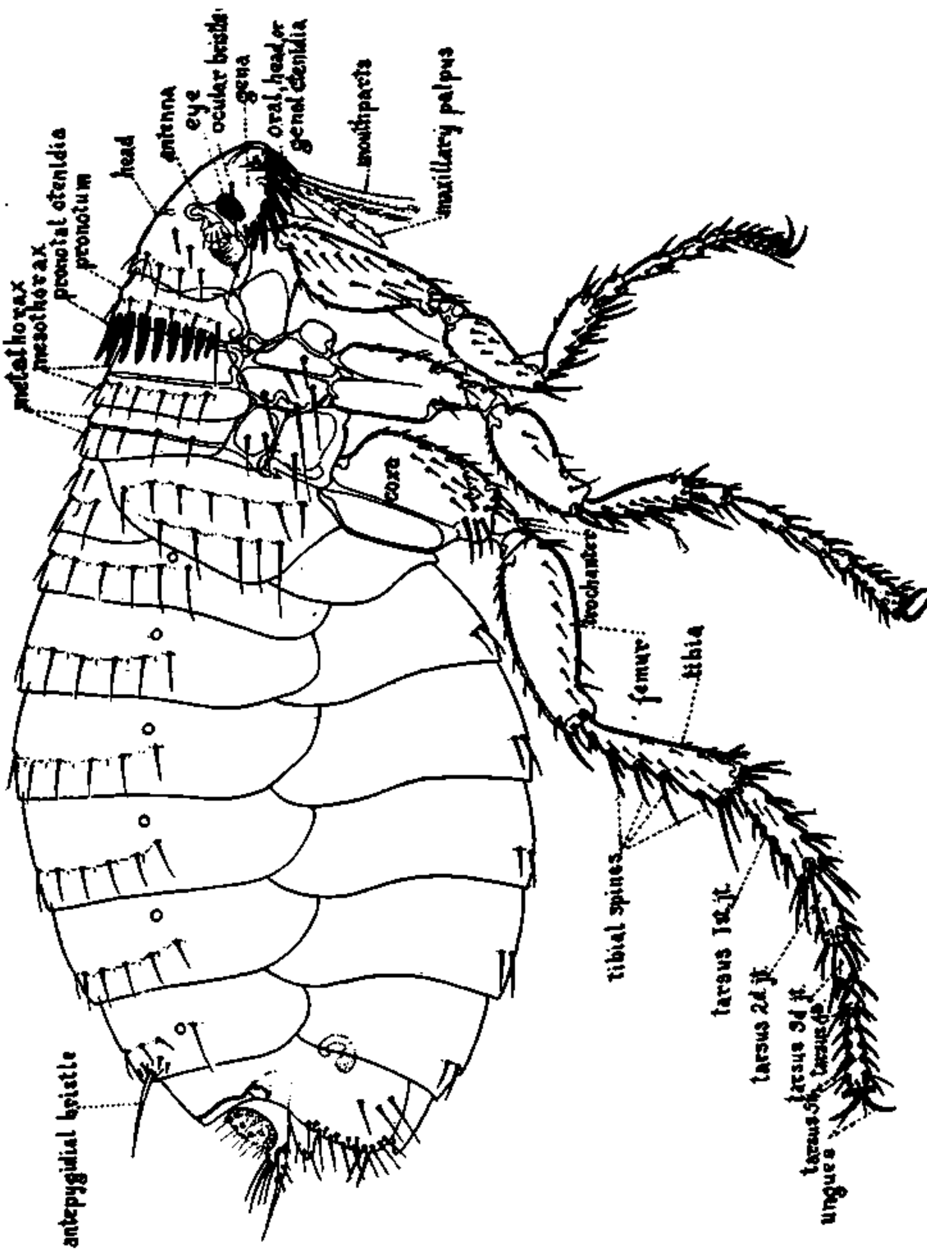

FIG. 171. — Showing principal characters used in the identification of Siphonaptera (fleas). × 45.

11° C. to 15° C. it lasted about fourteen days. Atlantic Coast observers have found that this stage may be passed in from two to four days.

The embryo is provided with a sharp spine on the head by means of which the egg shell is cut into shreds by a tumbling motion of its inhabitant, which is thus liberated. The larvæ (Fig. 172*b*) are very active, slender, 13 segmented, yellowish white maggots, with segmentally arranged bristles. The mouth parts are of the biting type and the larvæ subsist on organic matter. Very little food seems to be necessary for their development, though excrementous matter, *e.g.* feces from rabbits, rats, squirrels, and other rodents, also dry blood, sprouting grain, etc., favor growth. Excessive moisture is certainly detrimental to the life

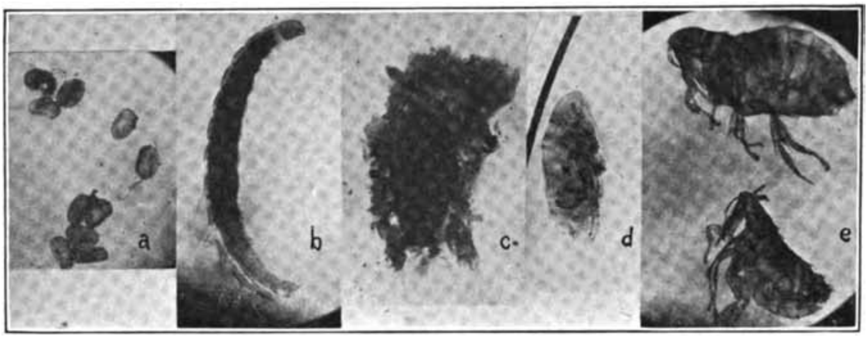

FIG. 172. — Showing life history of a rodent flea. *a*, eggs; *b*, larva; *c*, pupa in cocoon; *d*, pupa removed from cocoon; *e*, fleas, — male (lower), female (upper). × 12.

of the larvæ, although fewer fleas emerge from the cocoon during periods of hot dry weather. The larvæ are usually found in the crevices of the floor under the carpet or matting, in dusty stables, coops, kennels, nests of rodents, etc.

The length of the larval stage, during which there are two molts, is also influenced by temperature, and moisture in addition. Under laboratory conditions with room temperature this stage requires from twenty-eight to thirty days and over, though here again other workers report from seven to ten days. At the end of the larval period, the insect spins a silken, whitish cocoon (Fig. 172*c*) in which transformation takes place. The pupa (Fig. 172*d*) lies within this cocoon.

Warm, moist weather favors the metamorphosis of the pupa, from which the fully developed imago emerges in from ten to fourteen days.

Mitzmain (*loc. cit.*) observed one individual of the squirrel flea (*Ceratophyllus acutus* Bak.) from egg to imago with the following results: egg stage, eight days; first larval stage, six days; second larval stage, ten days; third larval stage, twelve days; cocoon (pupal stage), twenty-one days; total, sixty-seven days.

The following table (Table XIII), after the same author, indicates the wide variation in length of life history as reported by various authorities.

TABLE XIII

TIME REQUIRED FOR THE LIFE CYCLE OF FLEAS IN DIFFERENT COUNTRIES COMPILED FROM ACCOUNTS OF VARIOUS AUTHORS (MITZMAIN)

COUNTRY AND SPECIES OF FLEA	EGG	LARVA	PUPA	COMPLETE GENERATION
India:				
L. cheopis	2 days	1 week	7 to 14 days	21 to 22 days
Australia:				
P. irritans	6 days	12 days	14 days	4 to 6 weeks
Europe:				
P. irritans	4 to 6 days	11 days	12 days	4 to 6 weeks
Ct. canis	2 weeks	12 days	10 to 16 days	5 to 6 weeks
United States:				
Atlantic Coast:				
P. irritans, Ct. canis	2 to 4 days	8 to 24 days	5 to 7 days	2 to 4 weeks
Pacific Coast:				
P. irritans	7 to 9 days	28 to 32 days	30 to 34 days	9 to 10 weeks
L. cheopis	9 to 13 days	32 to 34 days	25 to 30 days	9 to 11 weeks
C. acutus	7 to 8 days	26 to 28 days	24 to 27 days	8 to 9 weeks
C. fasciatus	5 to 6 days	24 to 27 days	24 to 26 days	7 to 8 weeks

Longevity of Fleas. — It is of great importance to know how long a flea will live with and without food under various conditions. If not provided with a moist medium in which to live and at the same time deprived of the opportunity of feeding on a warm-blooded animal the majority of fleas die in about six days or less. In a moist medium such as wheat grains and sawdust (moistened), Mitzmain has kept squirrel fleas alive from thirty-eight days in one case to sixty-five days in another, the former a male, the latter a female. Rat fleas on human blood alone averaged eight and one half days (maximum seventeen) for the males, and thirty-two and four fifths days (maximum one hundred and sixty) for the females.

Hosts and Occurrence of Species. — As will be seen later in this chapter, the rodent fleas are most important from the public health standpoint, and transference from host to host of different species is a well-known habit, adding much to the danger of disease transmission.

It is true that ordinarily a certain species of flea is found to predominate on a given species of host, for example *Ctenocephalus canis* Curt. on the dog, *Ceratophyllus fasciatus* Bosc. on the rat in the United States, *Xenopsylla cheopis* Roth. on the rat in India, *Ctenopsylla musculi* Duges on the mouse, *Pulex irritans* Linn. on the human, etc.

For example, in an unpublished report to the writer on the species of fleas found on rats in San Francisco, Rucker states that a great preponderance of the rat fleas recovered in San Francisco are *Ceratophyllus fasciatus* as based on 10,972 specimens as follows:

Ceratophyllus fasciatus	68.07 %
Xenopsylla (Læmopsylla) cheopis	21.36 %
Pulex irritans	5.57 %
Ctenopsylla musculi	4.48 %
Ctenocephalus canis	.52 %

The following tables (Tables XIV–XX) adapted after McCoy[1] throw much light on the interchange of hosts and predominance of species:

TABLE XIV

FROM BROWN RATS (*Mus norvegicus*)

No. of Rats Combed	C. fasciatus		L. cheopis		P. irritans		Ct. musculi		Ct. canis	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
606	570	1252	790	1146	225	425	44	137	13	15

TABLE XV

FROM BLACK RATS (*Mus rattus*)

No. of Rats Combed	C. fasciatus		L. cheopis		P. irritans		Ct. musculi		Ct. canis	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
11	7	32	6	5	0	0	4	17	0	2

TABLE XVI

FROM MICE (*Mus musculus*)

From an unknown number of *Mus musculus*

	C. fasciatus		L. cheopis		P. irritans		Ct. musculi		Ct. canis	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	1	5	2	0	0	0	3	10	0	0

[1] McCoy, George W., 1909. Siphonaptera observed in the Plague Campaign in California, etc. U. S. Public Health Reports, Vol. 24, No. 29.

TABLE XVII

From California Ground Squirrels (*Citellus beecheyi*)

No. of Squirrels Combed	C. acutus		Hop. anomalus	
	Male	Female	Male	Female
132	2065	2306	86	140

TABLE XVIII

From the Dog (*Canis familiaris*)

No. Combed	Ct. canis		P. irritans		Ct. felis		C. acutus	
	Male	Female	Male	Female	Male	Female	Male	Female
4	10	44	8	17	0	1	1	0

TABLE XIX

From the Cat (*Felis domestica*)

No. Combed	Ctenocephalus felis	
	Male	Female
2	5	15

TABLE XX

From Man (*Homo sapiens*)

No. of Individuals	P. irritans		Ct. felis		Ct. canis		C. acutus	
	Male	Female	Male	Female	Male	Female	Male	Female
29	117	220	1	0	1	0	1	2

Light Reactions. — In a series of light reaction experiments by the writer on two species of fleas, *Pulex irritans* and *Ceratophyllus acutus*, it was found that the former reacts positively and directly to light (incandescent) at 10 C.M., 83+ C.M. and 100 C.M., and is indifferent to 7− C.M., while the latter species reacts negatively to higher intensities, such as 46+ C.M. and 83+ C.M., and is indifferent to lower intensities such as 9+ C.M. and 7− C.M.

The larvæ of *C. acutus* react in the main positively to light in their early stages, becoming more and more negative as they grow older. An intensity of 8.38 C.M. was used at intervals of three and five days.

Chemical Experiments. — To determine the lethal property of various chemicals, a series of experiment vials were made after the fashion of cyanide bottles for killing insects, *i.e.* a chamber was prepared into which cotton was placed soaked in the material to be tested and covered with dry blotting paper, the fleas thus did not come in direct contact with the chemical.

It was found that certain essential oils, such as lavender, citronella, mirbane, caraway, peppermint, eucalyptus and pennyroyal have a stupefying effect on fleas when used in strong concentrations, 50 per cent and over. It is quite probable that rubbing the body, particularly with oil of citronella, would act as a fairly good repellent.

Systematic. — Over 300 species of fleas have been described, of which number only a few need to be considered here, particularly those affecting rodents and man. The Siphonaptera (also referred to as Aphaniptera) are commonly divided into three families, viz., Sarcopsyllidæ, Pulicidæ and Ctenopsyllidæ. The following keys for the classification of fleas together with descriptions are adapted mainly after Banks.[1]

1. Thoracic segments much shortened and constricted; labial palpi apparently not jointed; third joint of antennæ without subjoints; no ctenidia; abdomen of female becomes more or less swollen . . *Sarcopsyllidæ*
   Thoracic segments not shortened nor constricted; labial palpi with joints; third joint of antennæ with several more or less distinct subjoints; ctenidia often present; abdomen of female never distinctly swollen 2
2. Posterior tibial spines in pairs . . . . *Pulicidæ*
   Posterior tibial spines mostly single and more numerous . *Ctenopsyllidæ*

Family Pulicidæ

1. Head without ctenidia; eyes distinct 2
   Head and pronotum with ctenidia; last tarsal joint with four pairs of lateral spines 5
2. Pronotum without ctenidia 4
   Pronotum with ctenidia 3
3. Female with one antepygidial bristle on each side . . . *Hoplopsyllus*
   Last tarsal joint with five pairs of lateral spines; female with two to five antepygidial bristles each side . . . . *Ceratophyllus*

[1] Banks, Nathan, 1910. The ectoparasites of the rat. A symposium on "The Rat and its Relation to the Public Health." U. S. Pub. Health Service Bull., Washington, D.C.

4. Mesosternite very narrow, without internal rod-like incrassation from the insection of coxa upward . . . . *Pulex*
   Mesosternite with a rod-like internal incrassation from insection of coxa upward . . . . *Xenopsylla*
5. Eyes rudimentary; female with two to five antepygidial bristles each side . . . . *Neopsylla*
   Eyes distinct; female with one antepygidial bristle each side *Ctenocephalus*

Family Sarcopsyllidæ

"The fleas of this family are commonly called 'chigoes,' 'jiggers' or sand fleas. The head is usually larger proportionately than in other fleas; there are no ctenidia on head or pronotum; the thoracic segments are extremely short, and in the female the abdomen enlarges with the development of the eggs. They do not hop about as other fleas, but remain on the spot to which they have attached themselves, until they die. Frequently the adjacent skin grows over them, forming a swelling of considerable size."

1. Angle of head acutely produced; fifth tarsal joint of hind legs without heavy spines; few spines on the legs . . . . *Sarcopsylla*
   Angle of head not produced, obtuse; fifth tarsal joint with heavy lateral spines and other spines on other parts of the legs . . *Echidnophaga*

Family Ctenopsyllidæ

"To this family belongs the *Ctenopsylla musculi* Duges (Fig. 173).

"This was formerly placed in the genus *Typhlopsylla*. The head is rather acute in front and has four ctenidia each side; the eyes are very small; the pronotal comb has 22 spines; each dorsal segment of the

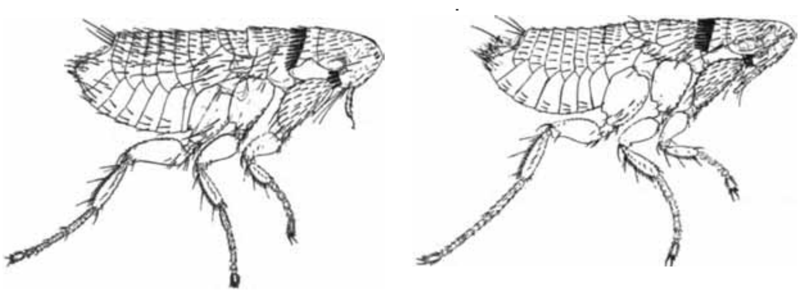

FIG. 173. — *Ctenopsylla musculi*, a mouse flea; male, right; female, left. × 17.

body has two rows of hairs; the basal row of smaller hairs. The proportions of joints in the hind tarsus are: 45–25–17–8–14. Length 1.8 to 2.5 mm. This species is abundant on rats and mice in Europe and other countries; recently it has been taken in California and Florida on rats and mice."

The Commoner Species

Pulex irritans Linn. (Fig. 174). "The mandibles reach about halfway down on the anterior coxæ; the head is regularly rounded in front; two bristles on the gena, one placed low down just above the maxilla, the other below the eye; there are no transverse rows of bristles

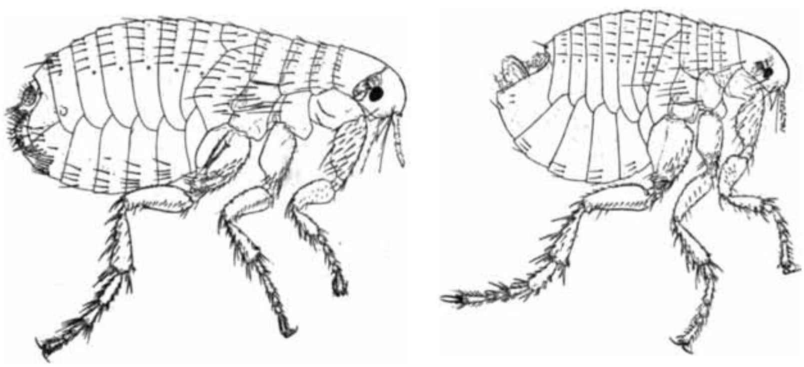

Fig. 174. — *Pulex irritans*, the human flea; male, right; female, left. × 17.

on the vertex, and but one row of bristles on each abdominal tergite. The proportions of the joints of the hind tarsus are: 5–30–18–12–32. Color, usually yellow-brown. Male, 1.6 to 2 mm.; female, 2 to 3.5 mm.

"This, the human flea, is quite cosmopolitan, but more abundant in warm countries than elsewhere. It occurs on many domestic animals and has frequently been taken from rats in California and elsewhere; it also occurs on skunks."

Ctenocephalus canis and *felis* (Fig. 175). "The common fleas on cats and dogs, as well as on man, belong to two species long kept under

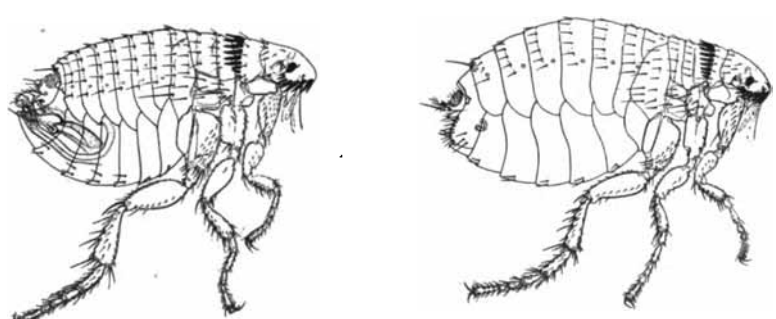

Fig. 175. — *Ctenocephalus canis*, the cat and dog flea; male, left; female, right. × 17.

one name (*C. canis* or *C. serraticeps*), but lately shown by Rothschild to be distinct. Both have a comb of eight spines on the head and sixteen spines in pronotal comb; the proportions of joints in the hind tarsus are: 40–24–15–10–24. They may be separated as follows:

1. In the female the head is fully twice as long as high (seen from side); the first spine of genal comb is two thirds the length of the second; in male the manubrium of claspers is barely enlarged at tip; and with two rows of hairs on disk of movable finger . . . . *C. felis* Bouché
   In the female the head is less than twice as long as high (seen from side); the first genal spine in the head comb is only about one half the length of the second; in the male the manubrium of clasper is very distinctly enlarged at tip; but one row of hairs on the disk of the movable finger . . . . *C. canis* Curtis

Ceratophyllus fasciatus Bosc. (Fig. 176). "There are eighteen or twenty spines in the pronotal comb; there are three bristles in front of eye and in female two, and in male four in front of these; there are

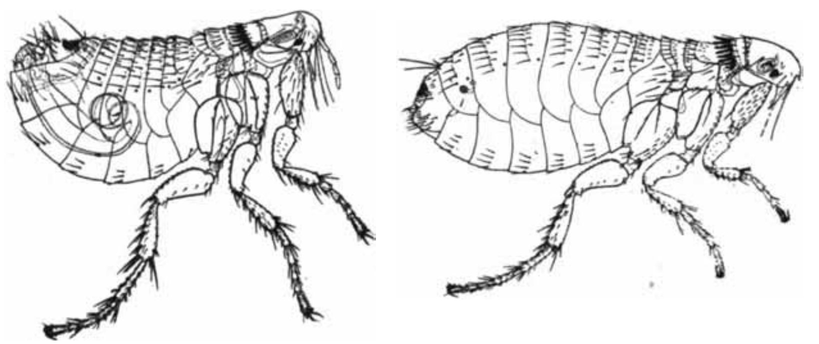

FIG. 176. — *Ceratophyllus fasciatus*, the rat flea; male, left; female, right. × 17.

three or four hairs on the inner surface of the hind femur; the proportions of joints in the hind tarsus are: 50–33–20–11–21. The manubrium of the male claspers is very long and slender, and some of the bristles on the movable finger are as long as the joint. Length, male, 1.8 mm.; female, 2.5 mm.

"It has been recorded in California in rats, mice, skunks and man. It is also common in Europe and elsewhere on rats, mice and other small animals."

Ceratophyllus acutus Baker (the squirrel flea) (Fig. 177). "This species is readily known by having a spine at tip of the second joint of hind tarsus longer than the third joint and reaching over on to the fourth joint; the abdominal tergites have each two rows of bristles; the male claspers are very large and long, sickle shaped. Color, pale brown. Length, 3 to 3.5 mm."

Ceratophyllus niger Fox. "This species has the pronotal ctenidia of about 26 spines; there are a few hairs on the inner surface of hind femur; apical spines of second joint of hind tarsus not longer than third joint; three hairs in front of the eye and three in front of these;

movable finger of claspers with five slender bristles on the outer edge. Color, very dark brown. Length, 3.5 mm.

"Taken in California from *Mus decumanus* and from man."

Ceratophyllus londinensis, Rothsc. "This species is closely allied to *C. fasciatus*, and best separated from it by the shape and armature of the genital parts; the manubrium is not as long as in that species,

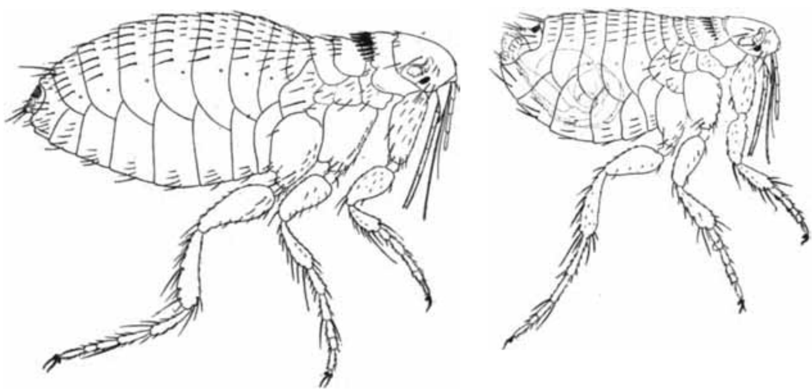

FIG. 177. — *Ceratophyllus acutus*, the squirrel flea; male, right; female, left. × 17.

and the bristles on the movable finger are shorter; the third joint of the maxillary palpi is proportionately longer than in *C. fasciatus*. There are three bristles in front of the eyes and four or five in front of these; there are a few hairs on the inner surface of the hind femur; the proportions of the joints in the hind tarsus are: 46–30–18–11–18.

"It has been recorded by Dr. Fox from *Mus rattus* in California, and is known from rats and mice from several parts of Europe."

Xenopsylla cheopis Rothsc. (Fig. 178). "The mandibles reach nearly to the end of the anterior coxæ; there are no ctenidia on the

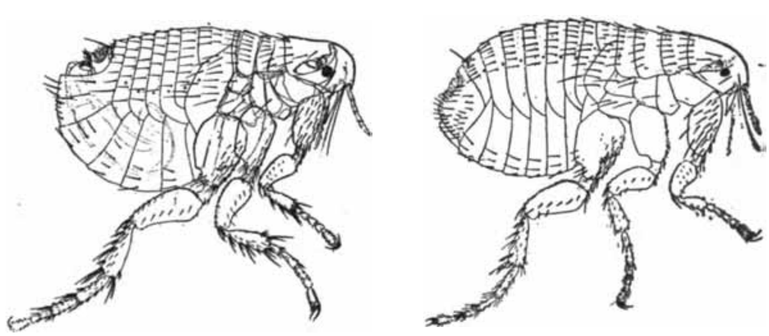

FIG. 178. — *Xenopsylla cheopis*, the oriental rat flea; male, left; female, right. × 17.

head or pronotum; two bristles on gena; oral bristles placed low down just above the base of the maxilla; ocular bristle in front and just above the middle of the eye; the eyes are distinct; each abdominal tergite has but one row of bristles; the hind femur has a row of about eight bristles; the proportions of the joints in the hind tarsus are as follows: 40–30–16–10–20. Color, light brown. Male, 1.5 to 2.0 mm.; female, 2 to 3.0 mm.

"This is a true rat flea, but will readily bite man, and is the species chiefly concerned in transmitting the bubonic plague. It is widely distributed, especially in seaport towns."

Hoplopsyllus anomalus Baker. "The mandibles scarcely reach halfway down on the anterior coxæ; upon each are two large spines; the pronotal comb has about nine spines each side; and each abdominal segment has but a single row of bristles. The hind femora have six to eight bristles on the side; the proportions of the joints in the hind tarsus are: 26–16–8–5–13. Color, dark reddish brown. Female, 2.5 mm.; male, 1.5 mm.

"Described from a spermopile from Colorado and recorded by Dr. Fox and Professor Doane from *Mus norvegicus* from California."

Echidnophaga gallinacea Westw. "This species has the body almost as broad as long, and of a red-brown color; one bristle in front of eye and six on each metathoracic pleuron; each abdominal tergite has on each side near the median line a single hair; the spiracles are situated well down on the sides. Length: male, 0.8 to 1.2 mm; female, 1 to 1.8 mm.

"This species is a fairly common pest of poultry and dogs in warm countries, and is called the 'chicken flea,' or 'stick tight.'"

Sarcopsylla penetrans Linn. This species differs from the above in that the eyes and antennæ are situated in the anterior half of the head, and the metathoracic scales are rounded.

Plague. — Plague is a bacterial disease traceable to *Bacillus pestis*, runs a rapid course, presents a high mortality, 20 per cent to 95 per per cent, depending upon hygienic and social conditions, and while it has appeared in devastating epidemics in temperate climates, it is endemic in certain warmer countries, particularly southern India and China.

Three forms of the disease may be considered; namely, *bubonic*, *septicæmic* and *pneumonic*. The incubation period varies from two to eight days ordinarily, according to Manson, though longer and shorter periods have been observed. In the bubonic plague, which constitutes by far the greater percentage of the cases, there appear characteristic swellings (buboes) in the groin (femoral glands), axilla (axillary glands) or other parts. These buboes vary from 2 cm. to 10 cm. in diameter; these appear within a day or two. In septicæmic plague the bacilli appear in the blood in large numbers, there is a comparative absence of swellings, the disease is very virulent and runs a very rapid course, terminating in death in from one to three days.

In pneumonic plague the seat of the disease is the lungs. This form is considered most fatal and most infectious.

The plague bacillus was discovered concomitantly and independently by Kitasato and Yersin in 1894, when it became established that rat plague and human plague are identical. Epidemics of plague in humans have evidently always been announced by fatal epizoötics among rats.

Plague Transmission. — Many theories have been advanced to account for the transmission of plague, notably soil and climatic conditions, but apparently insects were not suspected until the latter part of the last century. Nuttall [1] in 1897 demonstrated the presence of *B. pestis* in the bodies of bedbugs (*Cimex lectularius*) which had fed on the bodies of rats sick of plague. Simond [2] in 1898 first succeeded in transmitting plague from a sick rat to a healthy rat through the agency of infected fleas. Simond's work was discredited for a number of years, but was successfully repeated by Verjbitski [3] in 1903.

Liston [4] in 1904, working in Bombay, came to the following conclusions: (1) There was one flea infecting rats in India far more commonly than did any other, viz., *Xenopsylla* (*Pulex*) *cheopis* Rothsc.; (2) that these fleas when feeding on a plague rat harbored the plague bacillus in their bodies and that it multiplied therein; (3) that where fatal plague occurred many of these infected fleas were at large, and (4) that after a local epizoötic of rat plague, man was also found to harbor these rat fleas and might become infected as had the guinea pigs used in the experiment.

The following is a summary of experiments conducted by the Indian Plague Commission before and after its organization in 1905.

In the first instance healthy rats were confined in close proximity to rats which, inoculated with plague, had succumbed to that disease, and that previous to this had been artificially infected with rat fleas (*X. cheopis*). The separate confinement of the rats in each case was so arranged that both contact with and access to all excreta were excluded, although it was provided that the fleas could pass from the inoculated to the healthy rats; this transfer actually did take place and in many cases these fleas contained virulent plague bacilli; and when healthy non-immune rats were thus infected they died of plague to the extent of 79 per cent; this extent of infection fell to 38 per cent, when partly immune rats of local origin were employed.

That the plague had originated in the healthy rats through the intermediary of the rat fleas was further demonstrated by the fact that when they were actually transferred from artificially plague-infected to healthy English rats, the disease resulted to the extent of 61 per cent.

Further, on constructing a series of miniature houses (godowns) so

[1] Nuttall, G. H. F., 1897 (*loc. cit.*).

[2] Simond, P. — L. S., 1898. La propagation de la peste. Ann. de l'Inst. Pasteur, Vol. XII, p. 625.

[3] Verjbitski, D. T., 1908. The part played by insects in the epidemiology of plague. Journ. of Hyg., Vol. VIII, p. 162.

[4] Liston, W. G., 1905. Plague rats and fleas. Journ. Bombay Nat. Hist. Soc., Vol. XVI, pp. 253–273.

as to reproduce the conditions pertaining to ordinary domiciles, it was found that whenever these were so constructed as to admit rats to their roofs, but not to their interiors, guinea pigs confined therein became successively infested by rat fleas and infected by plague, but that in those houses to which rats could not gain access plague was originated in guinea pigs living therein, either by transferring rat fleas to them, derived from plague-infected guinea pigs, or on accidental admission of rat fleas from other sources. Also, that when so confined, guinea pigs had, under these conditions, died of plague; healthy flea-free guinea pigs, subsequently introduced, became plague smitten, and that the contagion remained in the place in proportion as the test animals were accessible to, and were found to be infested with, fleas. In other words, that "if the fleas be present, the rate of progress being in direct proportion to the number of fleas present." Further, that when in one of the houses, to the interior of whose roof fleas could not gain access, healthy guinea pigs were confined, guinea pigs became flea infested and infected when running on the ground, to a less extent when the cage was placed two inches therefrom, and not at all when it was suspended two feet above it. The fact that infection took place where rats were located two inches above the ground indicates that contact with infected soil is not necessary for plague to originate, and that "an epizoötic of plague might start without direct contact of healthy with infected animals."

To demonstrate that this communication of plague from guinea pig to guinea pig was through the intermediary of fleas, rat fleas were taken from a morbid guinea pig and allowed to feed through muslin on healthy animals. The positive outcome of this experiment proved the above statement.

The state of affairs that existed in actual domiciles in which plague occurred or had existed was next inquired into, advantage being taken of the fact that plague-susceptible guinea pigs would serve as hosts for, and for the collection of, fleas.

Guinea pigs free from fleas were introduced into rooms in which persons had died of plague, or from which plague-infested rats had been taken. They were allowed to be at large in these rooms for periods of from eighteen to twenty-four hours. These guinea pigs not only collected the fleas on their bodies, most of which were rat fleas, but 29 per cent of them contracted plague and died of plague within a few days after being restored to ordinary confinement. As before, many of the fleas which they yielded harbored plague bacilli in their stomachs, and were capable of infecting additional animals.

Further, after first washing the floors and walls of the rooms with an acid solution of perchloride of mercury, and so adequately disinfecting them for plague, but not for fleas, and then introducing guinea pigs, these latter became plague-infected if rat fleas were present.

That the infection was actually due to fleas was also shown by the positive results from fleas collected from rats occurring in plague-infected houses and transferring them to healthy rats or guinea pigs in the laboratory. These in due course became infected and died of plague.

Similarly fleas taken from the clean guinea pigs allowed to run in plague-infected houses, and transferred to fresh animals, communicated plague to them in eight out of forty experiments.

In the next place, plague-free white rats, guinea pigs and monkeys were placed in enclosures, which precluded contact as well as soil infection, in plague-infested rooms, pairs of one animal or another being used in each of the forty-two experiments of this class conducted, one individual being confined to a flea-proof receptacle and the other to an adjacent one accessible to these insects (one animal being thus a control). In the latter case plague resulted in four instances, or 10 per cent gave positive results.

As a variation of the same experiments, the enclosures for individual animals, whilst protected from soil or contact infection, were surrounded, as a screen to fleas, by 2½ inches of "tanglefoot" or were unprovided with this protection, the "tanglefoot" being replaced by sand. (Twenty-nine experiments were conducted.) In the latter case the animal became infested with fleas, one having as many as twenty; seven became fatally infected with plague. In the former individual fleas were only found on three of the rats and no animals became plague-infected.

Examining the fleas entrapped, 247 in number, it was found that 147 were human fleas, 84 were rat fleas, and 16 cat fleas. Moreover, a large proportion of each kind was examined. No plague bacilli were found in the cat fleas, 1 only in 85 of the human fleas was infected, and no less than 23 out of 77 of the rat fleas harbored plague organisms.

It was also shown that, when rats in the course of an epizoötic died of plague, the pathological features manifested in their bodies corresponded to those exhibited by artificially rat-flea-infected animals, and hence it was inferred that in nature and under experimental conditions the animals had alike succumbed to a single agency. This identity especially related to the site in which buboes arose, that in both instances, where the place of inoculation could be observed was similar.

Further Observations. — A study of mortality statistics shows that the greater percentage of plague occurs in the autumn, — September and October. This seasonal occurrence is undoubtedly due to climatic conditions, moisture and cold as affecting the life history and habitat of the rat and of the flea. Blue[1] reports a number of observations made in San Francisco indicating modes of infection; thus two small boys found the body of a dead rat in an unused cellar; the rat was buried with unusual funeral honors and in forty-eight hours both were

[1] Blue, Surgeon Rupert, 1910. Rodents in relation to the transmission of plague. U. S. Pub. Health Bulletin. The rat and its relation to the public health.

taken ill with bubonic plague. Again, a laborer picked up a dead rat with the naked hand and threw it into the bay. He was taken ill with plague three days later. The case of a physician's family is also cited in which foul odors pervaded their second story flat over a grocery store. On removing the wainscoting around the plumbing to ascertain the cause of the odor, two rat cadavers were found in the hollow wall. In two or three days thereafter the two members of the family who used the room sickened, one dying on the fifth day of cervical bubonic plague. Blue believes that the removal of the wainscoting set free infected rat fleas.

A most illuminating case is reported in the U. S. Public Health Reports (Nov. 7, 1913, p. 2356), viz. a fatal case of plague occurred in Manila (P. I.) in the person of an American, editor of the Manila Daily Bulletin. A plague rat had been found on September 6 in the block adjacent to the one in which the newspaper offices were located. The editor was admitted to the hospital September 19 and died at the Plague Hospital three days later. A mummified rat was found in the desk of the late editor, together with live fleas, *Xenopsylla cheopis*. Both the fleas and rat revealed bipolar staining organisms and inoculations into healthy laboratory rats produced typical cases of plague terminating fatally.

The facts that the mummified rat must have been dead at least two weeks and that the live fleas contained plague bacilli causes the comment to be made that "these facts furnish strong proof that plague might be introduced into a country without either the importation of human or rat cases of plague and that fleas might be alone concerned."

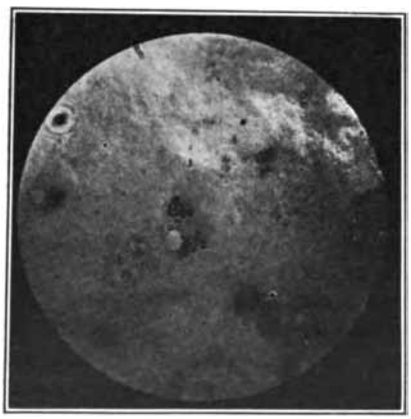

Fig. 179. — Showing *Bacillus pestis* from the intestine of a rat flea, *Ceratophyllus fasciatus*, taken from a plague rat. (Photograph by Mitzmain. Greatly enlarged.)

How the Flea Receives and Transmits Plague. — It was found by the Indian Plague Commission according to Fox (*loc. cit.*), that the average capacity of a flea's stomach (*Xenopsylla cheopis*) was .5 cubic millimeter and that it might receive as many as 5000 germs while imbibing blood from a plague rat. They further found that the bacillus would multiply in the stomach of a flea (Fig. 179) and that the percentage of fleas with bacilli in the stomach varied with the season of the year. In the epidemic season the percentage was greatest for the first four days, and on one occasion the stomach was found filled with *Bacillus pestis* on the twentieth day. In the non-epidemic season no plague bacilli were found in the stomach after the seventh day. They also found that in the epidemic season fleas might remain infective up to fifteen days, while in the non-epidemic season but seven days, and in the latter case the percentage of infection in animals was much less than in the epidemic season. They showed that while one flea was occasionally able to carry the infection this was not usual. It was found that both males and females were capable of transmitting the disease. As to the manner of dissemination the Commission found bacilli only in the stomach and rectum and never in the salivary glands nor body cavity and but rarely in the esophagus, and then only when the flea was killed immediately after feeding. As far as the writer knows the plague bacilli have not been demonstrated on mandibles, *i.e.* in a purely soiled condition, hence this fact and the absence of the bacilli from the salivary glands seems to preclude the possibility of direct inoculation by the bite, although it seems quite probable that plague bacilli might also be regurgitated, particularly when the flea's stomach is overfull and thus be injected at the time of biting. Very recently Bacot and Martin [1] have come to the conclusion that plague can be transmitted during the act of biting when a temporary blocking or obstruction of the proventriculus takes place causing bacillus-laden blood to be forced back or regurgitated into the wound, thus producing infection.

It will be observed that when a flea bites it commonly ejects feces and partially digested blood in the vicinity of the bite. It has been shown that an emulsion of plague flea feces placed upon the wound produced by the bite induces the disease in the animal, provided this is done within twenty-four hours after the insect has bitten, after which time the wound has probably healed sufficiently to exclude the organisms. The actual inoculation is, therefore, evidently an accidental process, i. e. the plague bacilli discharged *per anum* are *rubbed* into the bite of the flea either by the insect as it moves about or by the person in the act of scratching, — many persons very commonly scratch a flea bite until it bleeds. This method, together with that advanced by Bacot and Martin, probably explains the flea's rôle in the dissemination of plague.

Squirrels and Plague. — Plague has been found in a number of species of rodents other than rats, notably ground squirrels (*Citellus beecheyi*) (Fig. 180). In California the disease was demonstrated in ground squirrels under natural conditions in 1908 according to McCoy.[2] According to this author at the time of his writing (1910) about a dozen persons had contracted the disease under circumstances that pointed conclusively to squirrels as the cause. The two species of fleas commonly infesting the ground squirrel in California are *Ceratophyllus acutus* Baker and *Hoplopsyllus anomalus* Baker of which the former

[1] Bacot, A. W., and Martin, C. J., 1914. Observations on the mechanism of the transmission of plague by fleas. Journ. of Hygiene. Plague Supplement III, Jan. 14, 1914, pp. 423–439.

[2] McCoy, George W., 1910. Bubonic plague in ground squirrels. N. Y. Med. Journ., Oct. 1, 1910; see also U. S. Public Health Bulletin, No. 43.

is far more numerous. McCoy proved the first-named species a carrier as follows. He inoculated a ground squirrel subcutaneously with a broth culture of *B. pestis* derived from a human case of plague. This squirrel died on the fifth day, but three days before its death, 100 fleas, *C. acutus*, were put in the cage with it. The dead animal was removed from the cage while warm, and 27 live fleas taken from its body. Smears made of the crushed bodies of two of these fleas showed an abundance of pest-like bacilli in each. The remaining 25 fleas were put in a clean cage with a healthy squirrel. This animal died of subacute plague 10 days later, the buboes being in the region of the median, posterior inguinal and pelvic glands. A pure culture of *B. pestis* was obtained from the liver. McCoy rightfully concludes that the experiment is conclusive in showing that *C. acutus* may convey plague from a sick to a healthy squirrel. The squirrels used in the experiment were kept in quarantine for at least a month prior to their being used, which was necessary to exclude any naturally infected ones. McCoy found the bacilli in squirrel flea feces four days after removal of the fleas from the host.

FIG. 180. — Two varieties of the common "digger" ground squirrel of the Pacific Coast. The squirrel at left is the Douglas ground squirrel (*Citellus douglasi*), found along the coast north of San Francisco Bay; the one to the right is the California ground squirrel (*Citellus beecheyi beecheyi*), the common ground squirrel of the interior valleys and a carrier of bubonic plague. (Photo by University of California Museum of Vertebrate Zoology.) × .16.

Flea Control. (*A*) *Fleas in the House.* — The commonest household flea in Europe is *Pulex irritans*, the human flea, also predominating in California, while *Ctenocephalus canis*, the cat and dog flea, is commonest in the eastern portion of the United States. Both species are very often present at the same time, and both species infest cats and dogs; as a matter of fact they have a wide range of host animals. Unless house dogs and cats are very carefully groomed and repeatedly washed with efficient insecticides the presence of these animals will always be a source of many fleas.

In treating a house for fleas it must be borne in mind that the larvæ develop primarily in the crevices of the floors, under carpets and mattings. The old-fashioned tacked-down carpets and mattings, still so commonly used, must be done away with, unless an insecticide is used, which when applied to carpets in wetting quantities does not injure the fabric. Benzine is often recommended, but its dangers must be considered, both before and after applying. The writer does not undertake the responsibility of recommending benzine for this purpose. With the removal of carpets and matting, floors can easily be moistened with an oil mop, using kerosene. All parts of the floor in all parts of the house must be reached. The odor of kerosene is not particularly disagreeable and at all events soon disappears. Treatment should be repeated at least once every three or four weeks during the flea season. This method of treatment has invariably given good results. Dr. L. O. Howard recommends a free sprinkling of pyrethrum powder as the easiest remedy to be applied, or washing the floors with hot soapsuds. Dr. Henry Skinner has successfully destroyed fleas in a badly infested room by sprinkling the floor liberally with about five pounds of flake naphthalene and closing the room for twenty-four hours. The acrid fumes destroyed the fleas and inflicted no material injury (Felt).[1]

(*B*) *Treatment of dogs, cats and other domesticated animals* kept in or near the house is essential to the control of fleas. Mats on which house pets sleep should be shaken out over kerosene, soapsuds or a fire every few days in order to destroy flea eggs which have fallen from the host when it shakes itself. The sleeping quarters should be liberally dusted with California buhach or pyrethrum powder. Fleas also breed abundantly in loose dry manure and débris in stables, chicken houses, yards, etc. A spray of high flash point fuel oil is very useful under these circumstances. The best method to keep cats, dogs, monkeys, etc., free from fleas is to give them frequent baths with warm water to which enough creolin is added to make a 2 per cent solution. If the animal is dipped in the solution, the eyes should be quickly rinsed or sponged with clear water.

Animals infested with fleas may also be liberally dusted with California buhach or pyrethrum powder. The dust rubbed well into the hair causes the fleas to drop off in a stupefied condition, when they can be brushed up and burned. If the latter is not done the insects soon revive and go about their " business " as usual.

(*C*) *Rat Control.* — Not only are rats an object of control because of their menace to health but they are also injurious in many other ways. According to Lantz[2] there are several species of house rats (Fig. 181), among them the black rat (*Mus rattus*), the roof rat (*Mus alexandrinus*) and the brown rat (*Mus norvegicus*), of which the last named species is by far the commonest. All of these species were imported from the Old World. The habits of house rats, except the roof rat, are generally quite similar, hence methods of control are alike applicable, and manifestly the control of the host involves the control

[1] Felt, E. P., 1909. Control of household insects. Museum Bull. 129. N. Y. State Museum, Albany, N. Y.

[2] Lantz, David E., 1909. How to destroy rats. U. S. Dept. of Agric., Farmers' Bull. 369.

of the flea. Rucker[1] has well said, "Rodent extermination is a problem with difficulties arising from the animal's highly developed regard for self-preservation. In the main, the rat requires two conditions for life. He needs plentiful food and places suitable for nesting and breeding. Eliminate either of these elements and you drive away your rats. Yet the problem remains far more difficult than shown in the simple terms of the above equation. The fabulous speed at which rats multiply will baffle all but the most determined and efficient efforts to exterminate them. Under normal conditions each female bears three litters a year and each litter produces ten young. Under conditions ideally favorable it has been computed that one pair of rats will, in

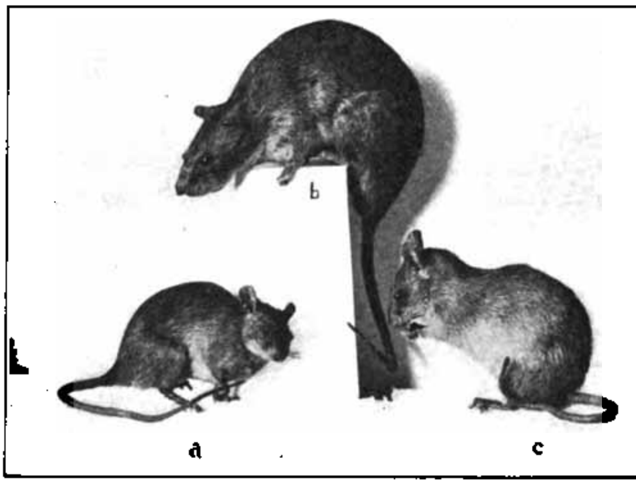

FIG. 181. — House rats. (a) *Mus rattus*, the black rat; (b) *Mus norvegicus*, the brown rat; (c) *Mus alexandrinus*, the roof rat. × .13.

five years, provided all can live so long, increase to 940,369,969,152. Such a result is, of course, impossible in nature. . . . . The size and frequency of rodent litters decreases proportionately with every cutting off of food supplies. Separate the rat from his pabulum and he will not breed so freely nor so often as when he is well fed. Destroy rat habitations and make it impossible for them to find new nesting places, and breeding will virtually cease, since the unsheltered progeny can no longer survive, and since the starving rats are driven to cannibalism in the struggle for existence."

Rat control may be accomplished by the proper combination of the following methods depending upon circumstances. (*a*) *Rat proofing* is by far the most important method. This is done by the use of concrete in building foundations and floors to stables, corncribs, poultry houses, outbuildings, dwellings, etc. Cement construction requires

[1] Rucker, William Colby, 1910. "Rodent extermination" in U. S. Public Health Bull. on "The rat and its relation to the public health," pp. 153–162.

comparatively little skill, is not expensive and is becoming an important factor in building the rat out of existence. (*b*) *Cutting off the food supply* essentially means (1) proper disposal of garbage, *i.e.* by burning the same speedily or placing it in covered metal garbage cans; (2) cremation of slaughter house refuse; (3) use of heavy wire netting for the protection of foodstuffs, feed bins, etc. (*c*) *Natural enemies* of the rat where otherwise not objectionable should be protected. Among the hawks, the red-tailed species (*Buteo borealis*) is said to be most efficient; among the owls, the barn owl (*Aluco pratincola*) is of greater importance; skunks and weasels are good ratters; a well-trained fox terrier is a very useful adjunct to every farm. (*d*) *Rat trapping* is best accomplished by means of the snap traps. These should be well smoked and baited with fried bacon securely tied to the trigger. Each time before using, it is well to scald the trap with hot water and "sizzle" the bait with a lighted match or torch. (*e*) *Rat poisoning* is ordinarily dangerous to the life of domesticated animals and children. Among the poisons commonly used are (1) *phosphorus paste* prepared by mixing crude phosphorus over heat with glucose, cheese, meat, etc. Danger from combustion must be borne in mind. (2) *Arsenic paste* consists of an arsenious acid (powdered white arsenic) combined with oatmeal, cheese, toast, etc. (3) Strychnine crystals (strychnine sulphate) may be placed in pieces of cheese or meat and put in the rat runways. *Extreme caution must be exercised in the use of rat poisons owing to danger to human life. State laws must be regarded in this respect as well.*

(*D*) *Squirrel Control.* — The most destructive as well as most dangerous species (as referred to public health) are the "digger" ground squirrels of the genus *Citellus* (Fig. 180). These squirrels live in colonies, ordinarily, and dig an extensive meshwork of connecting burrows. Their food consists of grain, seeds and fruit and is stored for the winter. The young are usually born in March and April in California and their litters number from five to ten. Three general methods of control are commonly employed. (1) Shooting and trapping. Shot guns carrying No. 7 or 8 shot are best employed, and chain traps are the best if trapping is to be done at all. (2) *Suffocation in the burrows* may be accomplished by either flooding with water or by the introduction of poisonous gases. Carbon bisulphide is the most efficient agent and is commonly employed. The following account of this gas and its use is based largely on the work of Simpson.[1]

Carbon bisulphide is obtained commercially in the form of a liquid, which is readily vaporized or is converted chemically into other gases. While it is the most useful material as applied against ground squirrels there are some objectionable features, namely, it is very inflammable, must be kept in tightly closed containers and under certain conditions

[1] Simpson, F., 1911. Ground squirrel eradication. California State Board of Health Bulletin, No. 8, Vol. 6, pp. 507–512.

may explode; furthermore during the dry season if "exploded" in the burrow there is danger of igniting dry grass or other inflammable material in the vicinity. If handled with as much care as gasoline, for example, the danger is not so great after all. The advantages in its use are, that it is readily converted into a poisonous gas, diffuses quickly, destroys life rapidly and can be used most readily during the rainy season when green food is abundant, thus preventing the most successful use of poisoned grain.

The bisulphide may be used in one of two ways, namely, in the simple liquid condition by evaporation, when there will be but little waste, or it may be used by igniting or exploding it. In either case it is suggested that from one to three days prior to the application of the poison all squirrel burrows in the area to be treated should be stopped with earth. The holes found opened indicate the burrow in which there are squirrels.

The method of applying the bisulphide by the ignition method is as follows: To handle a large area to best advantage two men working together is suggested. "One man is provided with a supply of 'waste,' 'sacking,' or other absorbent material, divided into a number of small balls about half the size of the fist. The bisulphide is carried in an ordinary one gallon oil can, and refilled from time to time from a supply kept in a cool place out of the sun. He is supplied with matches. His 'pardner' carries a mattock or long-handled shovel. On arrival at an opened squirrel burrow, a ball of 'waste' is saturated with two ounces of bisulphide, dropped deeply in the burrow and then a match applied. After a moment's time the man with the shovel stops with earth this burrow and all other burrows near from which the gas escapes. On subsequent inspection of the field all opened burrows will indicate holes lacking effective treatment." Exploding the bisulphide thus causes considerable gas to escape, but "the ignition produces a violent chemical reaction and as a result sufficient oxygen from the air combines with the carbon and sulphur elements to produce a volume of gas three times that which the original bisulphide would produce on evaporation. The gases produced, carbon dioxide and sulphur dioxide in the proportion of 1 to 2, seem just as effective as bisulphide of carbon, and the method is superior in that the explosion produced drives these gases deeply into the burrow." Two ounces or 60 cc. of the bisulphide produces about twelve gallons of gas.

To use the gas unexploded simply omit igniting it.

A much cheaper and more efficient method of destruction with carbon bisulphide has been devised by Long[1] and others, namely, a pump with a device measuring the quantity of liquid, and serviceable at all seasons of the year. The pump loaded with nine pints of bisulphide weighs twenty-five pounds. Refined bisulphide should be used in this

[1] Long, John D., 1912. A squirrel destructor. U. S. Pub. Health Reports. No. 98. (Reprint.)

pump because the metal is rapidly corroded by the crude material. The refined bisulphide is said to contain 99.92 per cent carbon bisulphide and 0.08 per cent sulphur in solution and no hydrogen sulphide nor sulphuric acid.

Only one half ounce (15 cc.) is required for each hole against two ounces by the ignition method, and it is claimed that the men using the pump have been able to treat from 200 to 250 holes with each gallon of the bisulphide, against 50 to 60 holes per gallon with the waste ball method above described. The cost of the apparatus is about $10 per machine and the cost per acre of treatment, going over the ground twice, is estimated at 20 cents with ten squirrel holes per acre.

The use of the apparatus is thus described (see Fig. 182): "Insert the hose in the squirrel hole at least one foot; then run one half ounce of bisulphide from the reservoir into the measuring cup; then turn cock with handle down to allow liquid to run into vaporizing chamber, meanwhile covering the hole with dirt with the aid of a mattock. Then pump thirty strokes (in cold weather use one ounce with forty strokes). This equals 12 cubic feet or 1.5 per cent bisulphide gas. Withdraw the hose, close hole opening by stamping in the dirt with the heel and proceed to the next hole."

(3) *Squirrel Poisoning.* — In the use of poison for squirrels several important factors must be considered, namely, it must not be distasteful to the rodents and must enter the circulation readily; the poison must be applied to food readily eaten by the squirrels and at a time when the usual green food is at its minimum. It has been found that strychnia sulphate (the pure alkaloid should not be used) is most effective, but the bitter taste must in some manner be concealed. The use of whole barley, *i.e.* threshed but still retaining the husk, is recommended by the U. S. Biological Survey. In this form the barley is not eaten by birds and is most acceptable to the squirrels; it is also cheaper in this form. Wheat is very acceptable to the rodents but when poisoned is very destructive to birds, particularly quail, doves and other grain eaters.

Piper of the U. S. Biological Survey has devised a formula whereby the bitter taste of the strychnine is delayed about two minutes, thus enabling the squirrel to fill its cheek pouches before the bitter taste is noted, — the formula is as follows:

Barley (recleaned)	18 pounds
Strychnine sulphate	1 ounce
Soda	1 ounce
Saccharine	1 dram
Thin soupy starch paste	1 pint
Corn sirup (Karo or equal)	2 oz.

Dissolve the strychnine in hot water; thicken with starch to thin soupy consistency. Mix the soda in ½ pint hot water; stir into poisoned starch. When effervescence ceases, add sirup and saccharine, apply to grain and continue mixing until mixed and dry.

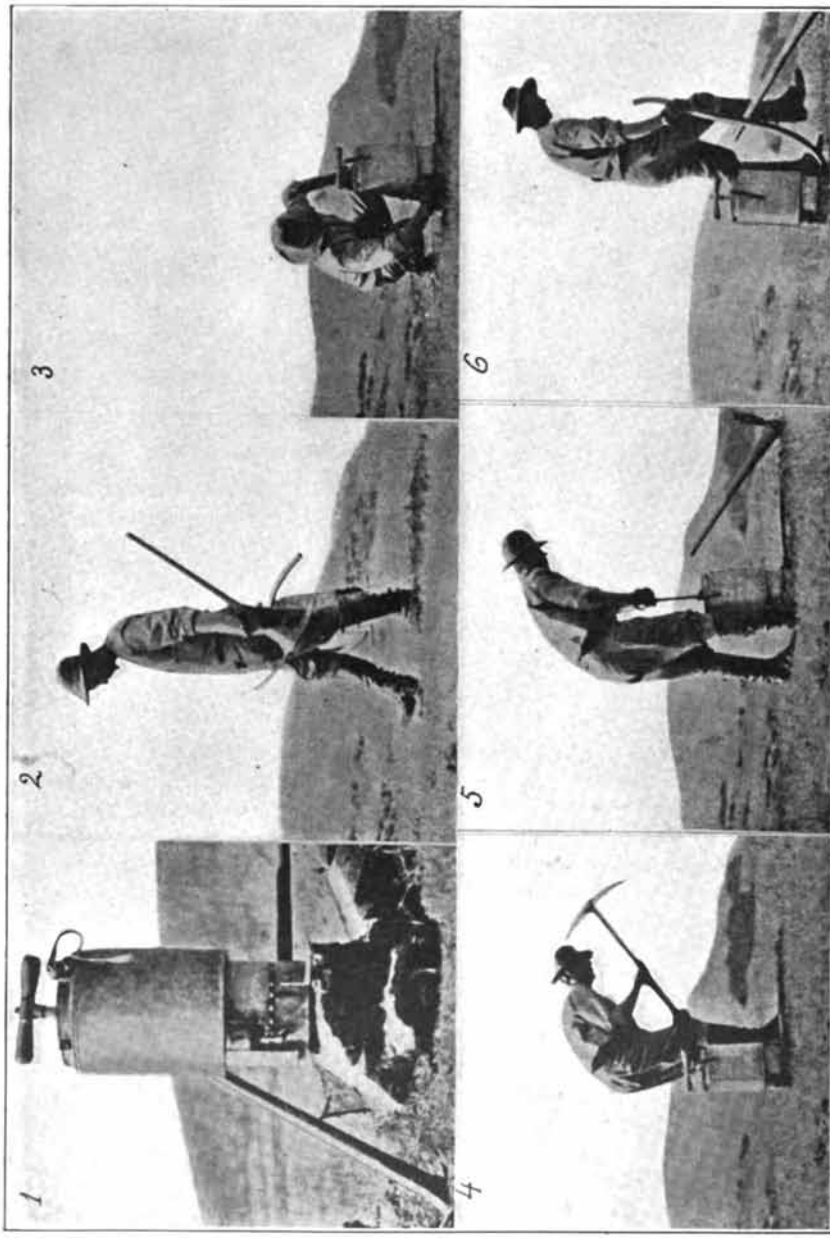

FIG. 182. — Squirrel destructor and its use. (1) The entire outfit ready for use; (2) Man with outfit looking for squirrel burrows; (3) Destructor in position, showing hose inverted in burrow and operator measuring off one half ounce of carbon bisulphide; (4) Closing the mouth of the burrow around the hose while the carbon bisulphide is running into the vaporising chamber; (5) Operator pumping 30 strokes and forcing into burrow 12 cu. ft. of a 1.5 per cent vapor of carbon bisulphide; (6) Operator closing with heel the hole in the burrow mouth by withdrawal of hose. (U. S. Public Health Service. By permission.)

According to Simpson (*loc. cit.*) grain poisoned with strychnine placed in proper containers will retain its poisonous character and remain effective for an indefinite period, but heavy dews and rain may remove the poison and destroy the efficiency of the grain in this respect. Therefore this method is applicable during the dry season only. The above author states that thirty kernels in the cheek pouches of squirrels rapidly prove effective, whereas sixty or ninety or more in the stomach may produce only a few convulsions and recovery ensues. He says, "This fact should be remembered in placing poison, for by scattering the grain a few kernels here and there near the burrow the squirrel is induced to store the grain temporarily in the cheek before a sufficient quantity is obtained for a meal. . . ." It should be scattered where the squirrel is accustomed to find food, and will probably be found most efficient if placed early in the morning, between the hours of 3 A.M. and 7 A.M.

The Chigoe Flea (*Sarcopsylla penetrans* Linn.), known as "jigger," "chigger," "chique," or "sand flea," is a tiny burrowing flea (Fig. 183) found in the tropical and antitropical regions of North and South America, also in the West Indies and Africa. Its introduction into Africa is said to have occurred as late as 1872. The chigoe is a reddish brown flea about 1 mm. in length, except that the impregnated female may become as large as a small pea, the head is proportionately large, there are no ctenidia on the head and thorax, the palpi are four-segmented and the mouth parts are conspicuous. The adult fleas are intermittent feeders but adhere closely to the host, the female when impregnated proceeds to burrow into the skin of the host. The eggs are deposited either in the ulcer or drop to the ground when discharged from the body of the female. The larvæ which emerge in a few days from the eggs are typical flea larvæ. Those hatching in the ulcer drop to the ground to develop under conditions similar to those having hatched on the ground. The larval period under favorable conditions probably requires not more than ten to fourteen days and the cocoon or pupal period about a like number of days.

FIG. 183. — The chigoe flea, *Dermatophilus penetrans*. × 35.

Pathogenesis. — The chigoes commonly attack the bare feet, these being nearest the ground, infesting the skin between the toes, and the soles; no part of the body is really exempt from attack. The burrowing female flea causes extreme irritation, the area surrounding the flea becomes charged with pus, producing a distinct elevation. The ulcerations due to the presence of numerous chigoes become confluent and very grave results are often involved. Wellman attributes the commonly observed auto-amputation of toes to the work of the chigoe.

Treatment and Control. — Where the chigoe flea commonly occurs, the habitations of humans and of domesticated animals (for these are also subject to attack) must be kept clean and free from dust, the floors may be swept up with a liberal sprinkling of naphthalene flakes, or with fresh buhach or pyrethrum powder. Where possible, kerosene treatment should be applied as described above for other fleas. Walking in bare feet should be avoided.

Parts of the body attacked by the fleas should receive immediate attention. The insect can be removed quite easily by means of a sterile needle or very fine pointed knife blade. The wounds caused by this treatment are then carefully dressed and allowed to heal. Applications of turpentine or other remedies serve to kill the fleas, which are then discharged by ulceration.

The Hen Flea, *Echidnophaga* (*Xestopsylla*) *gallinacea*, also known as the "stick tight" of poultry, is one of the worst poultry pests in many parts of subtropical America (Fig. 184). It commonly attacks poultry of all kinds, cats, dogs, horses and even humans. Osborn (*loc. cit.*) states that this species differs from the foregoing "in having the hind angles of the metathoracic scales angled instead of rounded and the eyes and antennæ in the posterior half of the head. It is from 1 to $1\frac{1}{2}$ mm. in length."

Fig. 184. — *Echidnophaga gallinaceæ*, the chicken flea or stick tight. × 25.

Before copulation both sexes are active, hopping about much as do other species of fleas. Shortly after feeding begins the females attach themselves firmly to the skin of the host and begin to burrow. At this time the sexes are in copulation. The burrowing females deposit their eggs in the ulcers which have been produced by the infestation. The larvæ crawl out of the ulcer and drop to the ground, where they grow rapidly, under favorable conditions, feeding on nitrogenous matter, dry droppings, etc. The full-grown larva, which is not unlike other flea larvæ, is about 4 mm. in length, having reached this stage in evidently about two weeks. The larva then spins a cocoon, pupates and in about two weeks emerges as a full-developed flea. The life history requires about four weeks, more or less, based on rather crude observations. The writer believes also that eggs are deposited in the dust or dry droppings of poultry, or in old nests, etc.

The fleas are most likely to attack the skin around the eyes or the anus or other bare spots. The ulceration and wart-like elevations around the eyes often become so aggravated that blindness results, the host is unable to find its food and death results.

To control the hen flea a thorough cleaning up is very necessary. The débris, dust, etc., must either be burnt or treated liberally with kerosene right in the yard so that the fleas do not become distributed while carrying away the refuse. The writer recommends that the yards and coops, particularly crevices, be thoroughly scalded out by liberal applications of boiling water or by the use of kerosene or a light fuel oil applied with a spray pump. Coops and yards which have crude oil floors are comparatively free from fleas and other parasites if otherwise kept in good condition. The hot water or oil treatment must be repeated once every three or four weeks during the flea season. The use of sheep dips, carbolic acid sprays, etc., does not, as a rule, give good results in controlling chicken fleas.

In addition to the above treatment infested chickens must also receive attention in order to destroy the ovulating female fleas. This may be done by dipping the birds in a 5 per cent solution of Zenoleum, Kreso or even Creolin. The use of naphthalene flakes in the nests is recommended or if this seems undesirable a liberal layer of slaked lime in the bottom of the nest may be substituted.

B. Louse Flies and Forest Flies

Order Diptera, Family Hippoboscidæ

Characteristics of Hippoboscidæ. — The family Hippoboscidæ is characterized by Williston as follows: "Head flattened, usually attached to an emargination of the thorax; face short; palpi wanting; antennæ inserted in pits or depressions near the border of the mouth; apparently one jointed, with or without a terminal bristle or long hairs. Eyes round or oval, sometimes very small; ocelli present or absent. Thorax flattened, leathery in appearance; scutellum broad and short. Halteres small or rudimentary. Abdomen sac-like, leathery in appearance, the sutures indistinct, legs short and strong, broadly separated by the sternum; tarsi short; claws usually strong and dentated; empodia usually present. Wings present or absent. . . . They are all parasitic in the adult stage upon birds or mammals. The larvæ are pupiparous, but pass nearly the whole of this stage within the abdomen of the parent, being extruded when nearly ready to transform into the mature fly." The mouth parts are tubular and are fitted for sucking blood. The species occurring on birds are included in the genera Olfersia and Ornithomyia, which according to Osborn are distinguished in that the former has two teeth under each claw and has no ocelli. The most important species is the sheep tick or sheep louse fly, *Melophagus ovinus* Linn.

The Sheep "Tick," *Melophagus ovinus* Linn. (Fig. 185), is a wingless species, reddish brown in color, about 5–7 mm. in length. The head is short and sunken into the thorax, the body is sac-like, leathery and spiny.

Life History. — The young of the sheep tick leave the body of the female ready to pupate. The extruded pupa (Fig. 185) during the course of a few hours becomes chestnut-brown in color, the secretion with which it is covered hardens and serves to glue the pupa firmly to the wool of the sheep. The pupæ are commonly found on infested sheep in the region of the shoulders, thighs and belly. Pupæ may be found on sheep at all times of the year, though the time required for development in the winter is longer than in the summer. Swingle[1] who has carried on most careful observations on this insect states that pupæ require from nineteen to twenty-three days to hatch in the summer, whereas nineteen to thirty-six days are required during the winter on sheep kept in the barn and probably forty to forty-five days on sheep out of doors. The time required for the females to reach sexual maturity is from fourteen to thirty days and over, when they begin extruding young at the rate of one about every seven or eight days. Swingle regards about four months as the average life of a sheep tick and that from 10 to 12 pupæ are deposited on an average.

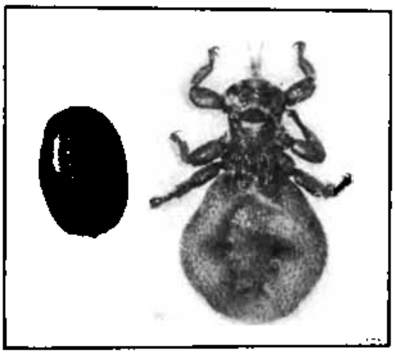

Fig. 185. — The sheep tick or louse fly, *Melophagus ovinus*. Pupa (left), adult (right). × 4.5.

The whole life of the tick is spent on the host; when off the sheep the insects die in from two to eight days, most of them dying in about four days.

Pathogenesis. — The presence of a few louse flies on the bodies of sheep does not materially affect them. Ordinarily the presence of the insect is indicated by the fact that the animal rubs itself vigorously, bites the wool and scratches. Badly infested animals show emaciation and general unthriftiness.

Control. — Since the principal time for migration from the sheep to the lambs is at shearing when the insects are taken off the hosts with the wool, it is wise to take particular pains at this time to store the wool at some distance from the lambs. Inasmuch as the ticks die within a week when away from the host, and cannot well crawl any great dis-

[1] Swingle, Leroy D., 1913. The life history of the sheep-tick, *Melophagus ovinus*. Univ. of Wyoming Agr. Exp. Sta. Bull. No. 99.

tance, the above suggestion is well worth considering. Swingle states that " a sheep free from ticks can be kept for months beside a heavily infested one with a tight partition only three feet high between them without becoming infested. . . . A bunch of females placed in the wool of a sheep will be found in practically the same place for two days. Males, however, are more inclined to migrate." A flock of sheep once freed from ticks can therefore be kept clean unless infested animals are introduced.

The writer has reasons to doubt the efficiency of the usual sheep dips such as " lime and sulphur " and tobacco decoctions in the destruction of the sheep tick, however, other dips, such as Kreso, Zenoleum and Chloronaphtholeum, if used as directed for sheep scab mites will kill the " ticks " but not the pupæ. The time for the second dipping is governed by the life history of the parasite, hence in warm weather (dipping for ticks is best done in the autumn), the second dipping should take place in about twenty-four days after the first.

No doubt a liberal use of buhach or pyrethrum powder, particularly as a winter treatment, would prove beneficial.

The louse fly of the deer is *Lipoptena depressa* Say (Fig. 186), an exceedingly common parasite of the deer. This species is smaller than *Melophagus ovinus*, otherwise similar; it is wingless when found on the host, but has well-developed filmy wings which are evidently lost later on (Fig. 186). These parasites have been found in chains, three or four attached to each other, the first tick drawing blood from the host, the second with its proboscis thrust into the abdomen (dorsally) of the first, the third drawing on the second and so on to the last most lucky individual.

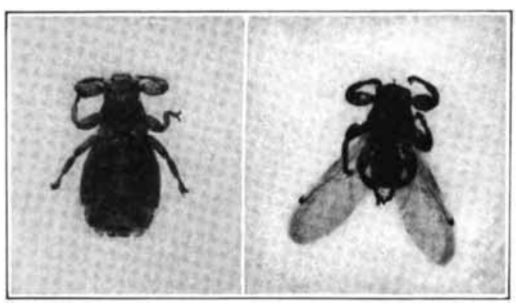

Fig. 186. — Louse fly of the deer, or deer tick (*Lipoptena depressa*), showing wingless and winged form. × 5.

The forest fly or louse fly of the horse is *Hippobosca equina* Linn. This species is quite large (length 8 mm.), is winged and a fairly good flier. It is common in many parts of the world but occurs rather infrequently in America. The damage which it does would depend entirely on its abundance.

CHAPTER XVIII

THE TICKS

Class Arachnida, Order Acarina, Superfamily Ixodoidea

Characteristics of Arachnida. — The general characteristics of the class Arachnida have already been pointed out in an earlier chapter, but it is in place to refer to these once more. In the arachnids the adults always have four pairs of legs (the larvæ are commonly hexapod), wings are absent as are antennæ and compound eyes. Simple eyes may be present or absent; when present they are often more than two in number. The mouth parts usually consist of a pair of piercing cheliceræ. The respiratory organ in some arachnids, for example spiders, is called a "lung book"; in many species however, particularly ticks, there is present a well-defined tracheal breathing system. The body is commonly divided into two parts, — cephalothorax and abdomen, the former bearing the walking appendages. In many species, for example, the ticks and mites, the regions of the body are fused. The sexes are distinct and there is often marked sexual dimorphism.

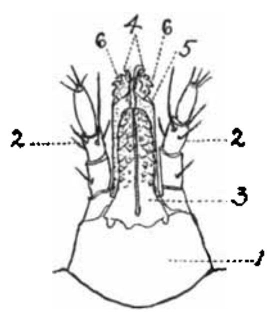

FIG. 187. — Capitulum of a tick (larval Argas), ventral aspect, showing (1) basis capituli; (2) palpi; (3) hypostome; (4) cheliceræ; (5) hood or sheath of cheliceræ; (6) denticles of cheliceræ. (Drawing by W. L. Chandler.)

Order Acarina. — To the order Acarina belong the ticks and mites. The cephalothorax and abdomen are fused, the larvæ have only three pairs of legs; the eyes in the parasitic forms are either very small or entirely wanting. The members of this group are never large, some ticks may be 15–16 mm. in length, while many of the mites are barely visible to the naked eye.

The Ticks. — The ticks are acari varying in size from 1 mm. in the seed tick or larval stage to about 15 mm. in the fully engorged mature female of several species. They are found in all parts of the world and are commonly regarded as pests of domesticated animals and frequently attack man.

The ticks belong to the superfamily Ixodoidea. They are blood-sucking arachnid parasites, body covered with a leathery, more or less glossy cuticle, the head or capitulum consisting of characteristic protrusible chelicerae and a serrate hypostome (Fig. 187). The females are capable of very great distention, having the appearance of a seed rather than that of an insect.

Life History. — The life histories of ticks vary considerably for the several species, hence it is quite impossible to generalize, except that it may be said that all species of ticks, with very few exceptions, pass through four stages, — *egg, seed tick, nymph* and *adult* and that from six weeks to over six months are required to pass through these four stages. Eggs are deposited by the fully engorged females, the number varying from 100 in some species to 5000 and over in others. The newly hatched larvæ, known as seed ticks, are hexapod (six-legged) and remain in this condition until the first molt. The nymph emerges from the first molt with its fourth pair of legs present, and remains in this stage until the second molt, after which the adult tick emerges; often a third or even a fourth molt or more takes place before the adult stage is reached. Copulation takes place after the last molt, when the females engorge and then deposit eggs. In the majority of species, the ticks drop off the host animal to molt, but in several species, notably the Texas cattle fever tick (*Margaropus annulatus*), the molting takes place on the host. Eggs are invariably deposited on the ground by the fully engorged females. There may be two or possibly three generations of ticks in one year under very favorable climatic conditions in such species as molt on the host.

The seed ticks emerging from the eggs on the ground commonly climb up grasses and other low vegetation, thus coming in easy reach of grazing or passing animals. The nymphs employ the same method.

Tick Mouth Parts. — The capitulum or head bears the mouth parts and accessory external structures (Fig. 187). The basal portion is known as the *basis capituli*, from which projects forward and dorsally a pair of protrusible *chelicerœ*. The distal portions (*digits*) of the chelicerae are divergent and provided with recurved teeth. Projecting forward and situated ventrally and median on the *basis capituli* is the *hypostome* bearing many recurved teeth. Laterally are located the *palpi* (one pair), consisting of four articles, of which two or more may be fused, — commonly only three are visible.

Feeding Habits. — When sucking blood both the hypostome and the chelicerae are inserted into the tissue of the host. Because of the recurved teeth the tick is enabled to hold so fast to the host that it is difficult to remove it without tearing the capitulum from the body of the tick. The tick itself, however, withdraws its mouth parts quickly and apparently with little effort by slipping the hoodlike portions of the capitulum over the relaxed mouth parts and by means of a quick jerk drops off and escapes.

The length of time that a tick remains attached in the act of feeding depends entirely on the species and the stage of development. The seed ticks commonly feed for a number of days; the nymphs and adults differ greatly in this respect, — thus the common poultry tick (*Argas persicus*) feeds nightly and intermittently, while the nymphs and adults of the cattle tick (*Margaropus annulatus*) feed from six to eight days before becoming engorged. Other species of ticks, notably the Pajaroello (*Ornithodorus coriaceus*), engorge themselves fully in from fifteen to twenty-five minutes.

Longevity.— The longevity and hardiness of ticks is something truly remarkable, a matter not to be overlooked in control measures, particularly pasture rotation in which starvation is the principal factor. Furthermore, fluids which destroy the life of most insects in a few minutes act very slowly on these arachnids, for example, immersion in 70 per cent alcohol will not kill the ticks for hours and xylol is resisted for about half an hour. The writer has found the poultry tick *Argas persicus* particularly resistant.

Unfed larval ticks of the above species remain alive quite readily for a month and would probably survive longer if kept in a moist chamber. Nymphs survive a longer time and the adults even longer than the nymphs. Nuttall[1] cites cases in which nymphs of this species survived two months, and adults (unfed) "a little over two years." Graybill[2] reports considerable variation in the longevity of the Texas fever tick, depending on the season of the year; unfed larvæ survived from 7 to 85 days (aver. 38.6) for July, and 30 to 234 days (aver. 167.4) for October. Nuttall[3] cites cases in which the larvæ of *Ixodes ricinus* survived 19 months, unfed nymphs 18 months and unfed adults 15 to 27 months.

Major Divisions (classification). — All ticks (superfamily Ixodoidea) are commonly divided into two families, viz.: Argasidæ (also referred to as subfamily Argasinæ) and Ixodidæ (also referred to as subfamily Ixodinæ). The presence of a *scutum* (or shield) located dorsally immediately posterior to the capitulum in the Ixodidæ is the most striking differential character. This character is absent in the Argasidæ.

The following table, on page 300, adapted after Nuttall (1908, *loc. cit.*), will be found useful in separating the two families. (See also Fig. 188.)

[1] Nuttall, G. H. F., and Warburton, Cecil, 1908. Ticks, a monograph of the Ixodoidea, Part I, Argasidæ. pp. x + 104 + 35. Cambridge (England), Univ. Press.

[2] Graybill, H. W., 1911. Studies on the biology of the Texas fever tick. U. S. Dep. of Agric., Bur. Animal Ind. Bull. 130.

[3] Nuttall, G. H. F., and Warburton, Cecil, 1911. Ticks, a monograph of the Ixodoidea. Part II, Ixodidæ. pp. xix + 105 + 348. Cambridge, (England), Univ. Press.

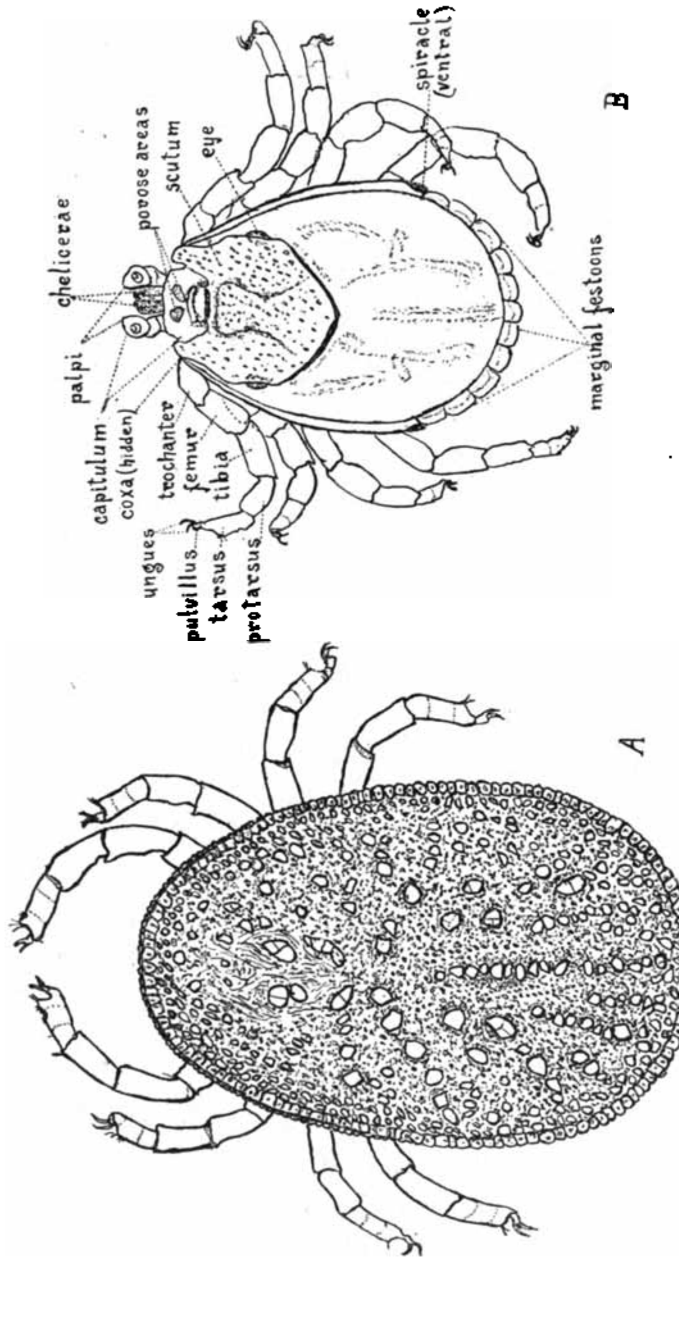

FIG. 188. — Showing certain useful characters in dorsal view to distinguish A, the Argasidæ (Argas), from B, the Ixodidæ (Dermacentor). (Drawings by W. L. Chandler.)

TABLE XXI

DIFFERENCES BY WHICH THE TWO FAMILIES OF THE IXODOIDEA MAY BE SEPARATED. (ADAPTED AFTER NUTTALL)

	ARGASIDÆ	IXODIDÆ
Sexual dimorphism	Slight	Marked
Capitulum	Ventral	Anterior
Base	No porose areas	Porose areas in ♀
Palpi	Leg-like, with subequal articles	Relatively rigid, of very varied form
Body		
Scutum	Absent	Present
Festoons	Absent	Generally present
Eyes (when present)	Lateral on supracoxal folds	Dorsal on the sides of the scutum
Legs		
Coxæ	Unarmed	Generally armed with spurs
Tarsi	Without ventral spurs	Generally armed with 1 or 2 ventral spurs
Pulvilli	Absent or rudimentary	Always present

THE IXODINE TICKS

The Texas Cattle Fever Tick

The Texas Cattle Fever Tick (*Margaropus annulatus* Say = *Boöphilus bovis* Riley) is economically considered the most important species of the family Ixodidæ (Fig. 189). It is restricted to North America, where it occurs south of the Mason and Dixon line. It is typically a cattle tick, although it occurs at times in smaller numbers on deer, sheep and other animals.

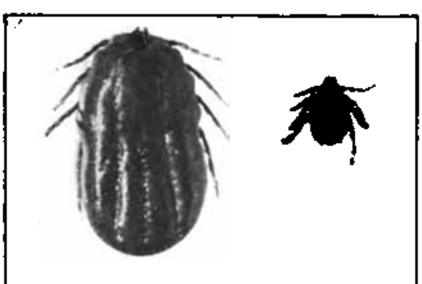

FIG. 189. — The Texas fever tick, *Margaropus annulatus*; female (left) and male (right). × 3.5.

Fully engorged females range in length from 10 to 12 mm., while the males range from 3 to 4 mm. The body of the female is about equally rounded both posteriorly and anteriorly with slight median incurving. The anterior pair of legs is set well out on the shoulders away from the capitulum (in Dermacentor close to the capitulum). The palpi are very short and stalky, so that the entire capitulum or head is inconspicuous. The relatively small (1+ mm. long) scutum or shield is solid chestnut brown in color. This is commonly the only species of tick in some localities with a chestnut-brown scutum. Two other species of ticks with a chestnut-colored scutum occur occasionally with the Texas fever tick, namely the "Lone Star Tick," *Amblyomma americanum,* which has, however, a distinct silver white circular spot at the posterior end of the scutum, and *Ixodes ricinus* and its varieties, *e.g. Ixodes californicus,* in which the capitulum is long, and the anterior pair of legs are attached close to it. Other technical diagnostic details are of course present in the latter two species.

The stigmal plates of *M. annulatus* are nearly circular; the porose areas are elliptical and far apart.

Economic Importance. — It has been estimated[1] that the annual losses to the South (U.S.) occasioned by the "cattle tick" directly and indirectly prior to 1906 amounted to $130,500,000. These losses are summed up as follows:

"1. Death, from Texas fever, of pure bred cattle imported from the North for breeding purposes.

"2. Death, from Texas fever, when cattle reared in isolated tick-free areas are unintentionally or accidentally placed with ticky cattle, or on tick-infested areas.

"3. Death of native cattle from excessive parasitism and fever, occasioned by the ticks.

"4. Universal loss of weight by all tick-infested cattle, and their failure to gain flesh at a rate great enough to make beef production profitable.

"5. The lower price which "Southern" cattle bring upon the market, regardless of how perfect their condition may be.

"6. Sterility induced in high-grade cattle by tick infestation.

"7. The expense of maintaining the Federal quarantine for the protection of the North against invasion by the tick, and the added expense of maintaining quarantine pens for Southern cattle shipped north for slaughter.

"8. The discouraging effect on the breeding of pure bred cattle in the South by reason of Southern breeders not being allowed to exhibit in Northern show rings.

"9. By no means least, the potential loss in fertility of Southern farm lands due to a one-crop system which, with the tick eradicated, would quickly give way to a diversified agriculture which would conserve and increase the fertility of our soils."

Life History of Texas Fever Tick. — Most careful observations on the biology of the Texas fever tick have been made by the Bureau of Animal Industry of the U. S. Department of Agriculture and the fol-

[1] State Crop Post Commission of Louisiana, 1906. Circ. No. 10, "The cattle tick."

lowing data is adapted after Graybill (1911, *loc. cit.*). The maximum number of eggs deposited by a female tick according to this author was 5105, minimum 357, with an average ranging from 1811 to 4089. The period of oviposition, time during which female deposits eggs, ranged from an average of 8.3 days for June (1907) to 127.5 days for November. The maximum period was 152 days and the minimum 3 days, depending on temperature mainly. The incubation period, also dependent on temperature, ranged from 19 days in summer to 180 days in the early autumn, with the average of 43.6 days for April, 26.3 days for May, 24.5 days for June, 20.5 days for July, 21.2 days for August and 35.9 days for September. The hatching period depends on the time when the eggs are laid, the eggs first deposited ordinarily hatching first. The average period ranged from 10.6 days for July to 36 days for October, with a maximum period of 49 days and a minimum of 4 days. The time during which the seed ticks remain alive, *i.e.* longevity of the newly hatched ticks, again varies considerably, depending on tem-

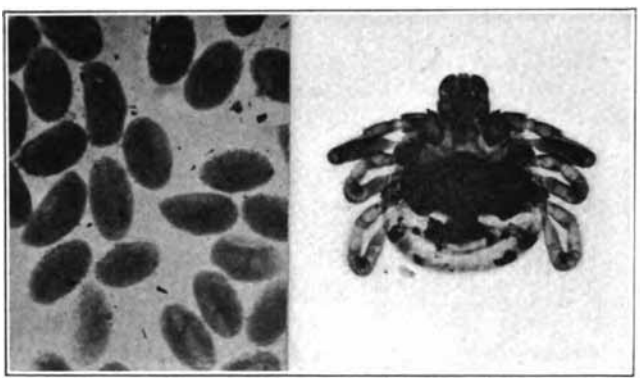

FIG. 190. — Eggs (left), larva (right), of the Texas fever tick, *Margaropus annulatus*. × 50.

perature; the longevity for April was found to be 65.1 days, May 62.3 days, June 65.1 days, July 38.6, August 84.9 days, October 167.4 days. The total average time for the non-parasitic period ranged from 86.9 days for June to 279.6 for October.

The three stages (Fig. 190) considered in the parasitic period of the ticks are larval (seed tick), nymphal and adult. As Graybill has well said, "The duration of each of these stages and the duration of a single infestation upon cattle during different portions of the year are of great practical importance. Upon the duration of an infestation depends the time animals must be kept on the tick-free fields in order to become free from ticks." This author has found that after the seed tick has attached itself to the host the minimum larval period ranges from five to seven days, the minimum nymphal period of females from nine to thirty days, and the adult from five to thirty-three days, with a total period of infestation, including the time for molting twice, which is accomplished on the host, at from thirty to sixty-six days.

The more striking differences between the life histories and a comparison of the life cycle of the Texas fever tick and the common dog tick (*Dermacentor electus*) are shown in the following two tables (Tables XXII and XXIII), adapted after Cotton:[1]

TABLE XXII

COMPARISON OF THE LENGTH OF THE LIFE CYCLE OF THE DOG TICK AND OF THE NORTH AMERICAN FEVER TICK IN SUMMER

(After Cotton, *loc. cit.*, 1908)

<table>
<tr><th>DOG TICK
(Dermacentor sp.)</th><th>NORTH AMERICAN FEVER TICK
(Margaropus annulatus)</th></tr>
<tr><td>I. Adult tick becomes engorged on host animal and drops to ground</td><td>Adult tick becomes engorged on host animal and drops to ground</td></tr>
<tr><td>II. Engorged tick begins egg laying (3000 ± eggs) after 3–5 days</td><td>Adult tick begins egg laying (3000 ± eggs) after 3–5 days</td></tr>
<tr><td>III. Seed ticks hatch from eggs in about 30 days</td><td>Seed ticks hatch from eggs in about 30 days</td></tr>
<tr><td>IV. Seed ticks bunch on grass and await coming of host animal, from one day to several weeks</td><td>Seed ticks bunch on grass and await coming of host animal from one day to several weeks</td></tr>
<tr><td>V. After feeding 7–12 days seed ticks drop to ground and molt</td><td rowspan="2">After feeding 7–12 days seed ticks molt on host animal</td></tr>
<tr><td>VI. Ticks crawl up on grass and await coming of second host animal from one day to several weeks</td></tr>
<tr><td>VII. Ticks get on second host animal and feed 5–10 days, then drop to ground and molt second time</td><td rowspan="2">Ticks feed 5–10 days, then molt on host animal and mate</td></tr>
<tr><td>VIII. Ticks crawl up on grass and await coming of third host animal from one day to several weeks</td></tr>
<tr><td>IX. Adult ticks mate and feed 5–8 days, then drop to the ground and lay eggs</td><td>Adult ticks feed 4–14 days then drop to the ground and lay eggs</td></tr>
</table>

[1] Cotton, E. C., 1908. Tick eradication. Agr. Exp. Sta. of the Univ. of Tennessee Bull. 81.

TABLE XXIII

SHOWING PROMINENT DIFFERENCES BETWEEN THE LIFE HISTORIES OF THE DOG TICK AND THE NORTH AMERICAN FEVER TICK

(After Cotton, *loc. cit.*, 1908)

DOG TICK (*Dermacentor sp.*)	NORTH AMERICAN FEVER TICK (*Margaropus annulatus*)
Leaves host animal for each molt	Never voluntarily leaves host animal from attachment as a seed tick until fully mature
Requires three separate host animals or may get on same host three times	Requires but one host animal to reach maturity and gets on this one animal but once
Can develop on a large number of different kinds of animals	Must find cow, horse, mule (deer or sheep) as a host animal or perish
Does not transmit Texas fever	Only natural means of transmission of Texas fever from one cow to another
Usually requires a whole year to complete its life cycle, from egg through seed tick, nymph, and adult, to egg again	Is able to complete its life cycle in about 60 days, thus allowing for three generations in one year, provided hosts are available
Because of the habit of dropping to the ground at each molt the parasitic and non-parasitic periods intermingle and therefore the life cycle cannot be divided into two distinct parts	Life cycle is divided into two separate and distinct parts; *parasitic*, passed *on* the host animal, and *non-parasitic*, passed *off* the host animal
The habit of dropping to the ground for each molt materially reduces the chances of the seed ticks of this species reaching maturity	The habit of remaining on the host animal until maturity renders it almost certain that every seed tick of this species finding attachment will reproduce itself
Since the species has but one generation per year the progeny of one adult tick will produce 1,050,000 eggs in a single season	Since this species has three generations per year the progeny of one adult tick will produce 5,825,036,452,578,000 eggs in a single season

Piroplasmosis applies to a group of diseases traceable to the Protozoön genus Babesia (Piroplasma), and related genera such as Theileria, Nuttalia, etc., belonging to the subphylum Sporozoa, class Telosporida, subclass Hæmosporida, order Xenosporida. The genus Babesia comprises pear-shaped (varying somewhat to oval), red blood-cell inhabiting parasites (Fig. 191). Unlike the Plasmodia there is little or no pigment, and multiplication is by division in twos. Ticks are the usual carriers in which there is hereditary transmission from the female tick to the egg, and thus to the larva and nymph which act as the infecting agents. The most important example of Piroplasmosis is Texas cattle fever.

Texas Cattle Fever. — *Babesia* (*Piroplasma*) *bigemina*, Smith and Kilbourne is the causative organism of Texas cattle fever, also variously known as red water, splenic fever, tick fever, etc. The disease is widely distributed, being endemic in southern Europe, Central and South America, parts of Africa, Mexico, the Philippines, and the southern United States where it has been known for more than a century, having been introduced into this country probably from Europe.

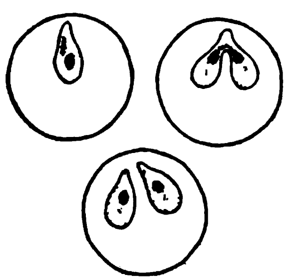

FIG. 191. — *Babesia bigemina* (*Piroplasma bovis*), showing three stages in intracorpuscular development. × 2000.

The name Texas fever became attached to the disease because of the large herds of cattle which were driven northward from Texas and gave a certain disease in some mysterious manner to Northern cattle that crossed the trail of the Southern cattle. The first account of the disease was given by James Mease in 1814 before the Philadelphia Society for Promoting Agriculture. In 1879, Salmon began an investigation of the disease; and in 1889, Theobald Smith made his epoch-making discovery of the intracorpuscular protozoan parasite inhabiting the blood of the diseased cattle. Immediately thereupon followed the experiments of Kilbourne, on suggestion of Salmon, which proved the disease to be tick-borne, a suspicion held as early as 1869 according to Smith and Kilbourne. Until that time (1889) infection was variously attributed to saliva, urine or feces.

The disease may assume either an acute or chronic form, the acute occurring during the summer months and the chronic during the autumn and early winter. The symptoms [1] of the acute form are as follows: The temperature often registers 106° to 108° F. within forty-eight hours after the first symptoms are noticed. The sick animal leaves the herd, stands with arched back and ears drooping, the muzzle dry, appetite lost and rumination stopped. There is constipation during the first stage of the disease, which may give way to diarrhea later. The manure

[1] Adapted largely after the description of L. L. Lewis, 1908. Texas fever. Okla. Agr. Exp. Sta. Bull. No. 81.

is frequently stained with bile and may be tinged with bloody mucus; the urine is often very dark red or coffee-colored. The blood becomes thin and watery, so that by making an incision into the tip of the ear and allowing the blood to flow over the hand it does not stick to the hand as does the blood from a healthy animal.

Vast numbers of red blood corpuscles are destroyed by the parasites, which accounts in a measure for the reddish color of the urine through the elimination of hæmaglobin by the kidneys; and it is believed that the excessive work that the liver has to perform in attempting to transform the excess of destroyed corpuscles into bile, causes this organ to become deranged in function, and eventually a complete stagnation may result with fatal termination. Mortality ranges from fifty to seventy-five per cent.

The chronic form of the disease is often hardly noticeable. The following comment by Lewis (*loc. cit.*) is significant: "This is the type of fever usually seen among Southern cattle. Death does not occur as a rule, but the loss in growth and general condition is such as to make this type of disease very important. It is this loss in growth and condition rather than an actual numerical loss by death that constitutes the great damage suffered by the stock industry of the South."

Babesia bigemina (Piroplasma (bovis) bigeminum), the causative protozoan parasite of Texas cattle fever, was discovered by Theobald Smith in 1889 and was called *Pyrosoma bigeminum*. The parasite (Fig. 191) is described by Smith and Kilbourne[1] as follows: "When blood is drawn from the skin during the fever, and examined at once with high powers (500 to 1000 diameters . . .) certain corpuscles will be found containing two pale bodies of a pyriform outline. One end of each body is round and the body tapers gradually to a point at the other. They vary somewhat in size in different cases, but the two bodies in the same corpuscle are as a rule of the same size. They are from 2 to 4 μ in length and 1.5 to 2 μ in width at the widest portion. Their tapering ends are directed toward each other and usually close together; their rounded broad ends may occupy various positions with reference to each other. They may be seen together with the axes of the bodies nearly parallel or they may be far apart, the axes forming a straight line. The bodies themselves have a homogeneous, pale appearance, contrasting markedly with the inclosing red corpuscles from which they are sharply outlined. There is no differentiation into peripheral and central zone, no granular appearance of the body. . . . When exposed to a temperature of 35° C. to 42° C. on the warm stage some of these bodies, by no means all, exhibited changes of outline. These may go on continuously in some bodies, in others quite slowly. The motion most frequently exhibited consists not so much of a thrust-

[1] Smith, T., and Kilbourne, F. L., 1893. Investigations into the nature, causation and prevention of Texas or Southern cattle fever. U. S. Dept. of Agric., Bur. Animal Ind. Bull. No. 1, 301 pp.

ing out and withdrawing of pseudopodia as of a continual recasting of the general outline of the body as we find it, for example, in the leucocytes of mammalian blood. . . . The number of infected corpuscles circulating in the blood during the high fever is usually quite small . . . from half to one per cent is near the truth in most cases. . . . Toward the fatal termination, there may be from 5 to 10 per cent of the corpuscles with the pyriform parasites present."

In 1888 an "investigation into the nature, causation and prevention" of the disease was undertaken by the United States Department of Agriculture, Bureau of Animal Industry, under the direction of Dr. D. E. Salmon. The work was done by Dr. Theobald Smith and Dr. F. L. Kilbourne and marks a most important epoch in our knowledge of protozoan diseases and in preventive medicine.

During a period of about four years of nearly continuous investigation, the problem was exhaustively studied in both the field and in the laboratory. The field experiments were carried along three different lines, viz.: "(1) Ticks were carefully picked from Southern animals so that none could mature and infect the ground. The object of this group of experiments was to find out if the disease could be conveyed from Southern to Northern stock on the same inclosure without the intervention of ticks. (2) Fields were infected by matured ticks and susceptible cattle placed on them to determine whether Texas fever could be produced without the presence of Southern cattle. (3) Susceptible Northern cattle were infected by placing on them young ticks hatched artificially, *i.e.* in closed dishes in the laboratory" (Smith and Kilbourne, 1893, *loc. cit.*).

Healthy native cattle (Washington, D.C.) were exposed to sick native cattle free from ticks for months without contracting the disease, proving that the excretions had nothing to do with the transmission of the disease. In the absence of ticks, sick animals are harmless. Again several thousand, mostly full-grown ticks, collected from cattle in North Carolina, were scattered over the ground in a field on September 13. Four native cattle were placed in the field Sept. 14; of these animals three contracted Texas fever. This experiment was repeated with five experimental animals, and a new-born calf, all of which contracted the fever. A yearling heifer was placed in a box stall and a number of young ticks, hatched artificially in glass dishes, were placed on the animal at intervals. The heifer contracted Texas fever. A repetition of this experiment on various occasions always gave similar results. It was definitely concluded that "Texas fever in nature is transmitted from cattle which come from the permanently infected territory to cattle outside this territory by the cattle tick (*Boöphilus bovis = Margaropus annulatus*) and that the infection is carried by the progeny of the ticks which matured on infected cattle, and is inoculated by them directly into the blood of susceptible cattle."

Just how the young tick becomes infected from the parent tick is still a question, but it seems reasonable to conclude that the protozoon migrates from the intestine of the parent, possibly in a manner similar to the development of the malaria parasite, eventually infecting the ovaries instead of the salivary glands as in the mosquito, and thus the ova become infected before ovulation and the newly emerged seed tick is consequently infective. The authors above cited state that the contents of the bodies of ticks in various stages of growth were examined microscopically with considerable care, but that the abundant particles resulting from the breaking up of the ingested blood corpuscles obscured the search so that nothing definite was discovered. "The very minute size of the microörganism renders its identification well-nigh impossible, and any attempt will be fraught with great difficulties."

Other tick carriers of the protozoon are *Boöphilus australis* Fuller and *B. decoloratus* Koch within their range.

Controlling the Texas Fever Tick. — This is accomplished in one of two general ways or by a combination of the two; namely, first by the application of tickicides on cattle, and secondly by pasture rotation resulting in the starvation of the seed ticks which have hatched from the eggs deposited by dropped ticks, the pasture being previously made free of ticks by a similar process. It is not the object of this work to give a detailed account of the methods employed, hence the reader is referred to Farmers' Bulletin 498, U. S. Department of Agriculture, for specific "Methods of exterminating the Texas fever tick."

First, agents for the destruction of ticks on cattle are ordinarily either *oil* or *arsenic*. If the former is used an emulsion is desirable, to be applied with a spray pump or in the form of a dip. An emulsion of crude petroleum recommended by the U. S. Department of Agriculture, Bureau of Animal Industry,[1] is prepared as follows:

Hard soap	1 pound
Soft water	1 gal.
Beaumont crude petroleum	4 gal.

This formula is sufficient to make five gallons of 80 per cent stock emulsion. For use this must be diluted with water to a 20 to 25 per cent emulsion, or one part stock emulsion to three or two and one-fifth parts of water.

To prepare the stock the soap should be "shaved up and placed in a kettle or caldron containing the required amount of water. The water should be brought to a boil and stirred until the soap is entirely dissolved. Enough water should be added to make up for the loss by evaporation during this process. The soap solution and the required amount of oil are then placed in a barrel or some other convenient re-

[1] Graybill, H. W., 1912. Methods of exterminating the Texas fever tick. U. S. Dept. of Agr., Farmer's Bull. 498.

ceptacle and mixed. The mixing may be effected by the use of a spray pump, pumping the mixture through and through the pump until the emulsion is formed. Only rain or soft water should be used for diluting." If hard water is used, it should be softened by adding sodium carbonate (sal soda), $\frac{1}{2}$ pound to every five gallons of water used. The Beaumont oil recommended has a "specific gravity ranging from $22\frac{1}{2}°$ to $24\frac{1}{2}°$ Beaumé, containing $1\frac{1}{4}$ to $1\frac{1}{2}$ per cent sulphur, and 40 per cent of the bulk of which boils between 200° and 300° C."

Arsenical dips are now more widely used than any other kind. The U. S. Department of Agriculture, Bureau of Animal Industry (Graybill, 1912, *loc. cit.*), recommends the following formula:

Sodium carbonate (sal soda)	24 pounds
Arsenic trioxid (white arsenic)	8 pounds
Pine tar	1 gal.
Water sufficient to make 500 gallons.	

The following directions are given by the Bureau of Animal Industry for the preparation and use of the above arsenical dip:

"In preparing the dip a large caldron or galvanized tank is required for heating the water in which to dissolve the chemicals. Twenty-five gallons of water should be placed in the caldron or tank and brought to a boil. The amount of sodium carbonate indicated in the formula is then added and dissolved by stirring. When this is accomplished, the required amount of arsenic is added and dissolved in a similar manner. The fire is then drawn, and the solution permitted to cool to 140° F., or this process may be hastened by the addition of cold water. The pine tar is then added slowly in a thin stream and thoroughly mixed with the solution by constant stirring. This solution should be diluted at once to 500 gallons.

"The caldron or tank and utensils used in preparing the dip should be kept free from grease or oil, as small quantities of these may envelop particles of arsenic and prevent or hinder the solution of the arsenic. It should also be borne in mind that when hard water is used in the preparation of the dip the dissolving of the sodium carbonate (sal soda) in the boiling water results in the formation of a fine white or gray insoluble powder or precipitate of lime salts which may be taken for undissolved arsenic, and thus lead to the belief that all of the arsenic has not gone into solution.

"The arsenical solution when prepared according to the above method should be diluted as soon as the pine tar has been added, in order that the tar may become properly emulsified. In the concentrated solution the tar tends to separate out, especially when the solution becomes cold, and collect in a layer at the bottom of the container. Even when the plan of immediately diluting the solution is followed a satisfactory emulsion is not always obtained, and some of the tar may separate and go to the bottom of the vat.

"If, however, the acids present in the tar are neutralized by the use of concentrated lye, a good emulsion of the tar in the diluted dip may be obtained.[1] The neutralization is effected by dissolving 1 pound of concentrated lye in a quart of water for every gallon of tar to be used and adding this solution to the tar, stirring thoroughly. When the acids of the tar have been properly neutralized the resulting mixture should be a bright, thick fluid of a dark brown color.

[1] This method of emulsifying the tar has been suggested by the Biochemic Division of the Bureau of Animal Industry.

Whether the acids have been neutralized or not may be determined by taking a small quantity of the tar on the blade of a pocket knife or on a sliver of wood and stirring it in a glass of water. If the acids have been neutralized, the tar will mix uniformly with the water; whereas, if they have not been neutralized, the tar will float about in the water in the form of various-sized globules that will settle to the bottom when the agitation of the water ceases. For all ordinary grades of tar one pound of lye to the gallon will be ample to effect neutralization, but if on testing it is found that this amount has not been sufficient, it will be necessary to add more lye solution, about a pint at a time for each gallon, until the test shows that the acids have been neutralized. The neutralized tar should be added to the diluted arsenical dip and not to the concentrated solution, with which it will not mix satisfactorily. When the neutralized tar is used the vat should be filled with diluted arsenic-soda solution prepared in the usual way. The required amount of neutralized tar, diluted with two to three times its volume of water, should then be added to the solution in the vat and thoroughly mixed with the same by stirring.

"Before filling a vat the capacity, at the depth to which it is necessary to fill it for dipping, if not known, should be calculated, and for future convenience the water line should be plainly marked at some point on the wall of the vat. Unless this is done it will be necessary either to calculate the amount of water in the vat each time it is filled or measure it as it is placed in the vat, both of which procedures will consume considerable unnecessary time. The most convenient way to get the water into the vat is to conduct it through pipes, either directly from a pump or from an elevated tank used for storing water for farm purposes. Frequently, however, it is not possible to bring the water to the vat through pipes, and it becomes necessary to resort to the laborious process of hauling it in barrels on wagons or sleds.

"In case the pine tar is added to the concentrated solution when it is made, in which case, as already stated, it is necessary to dilute the solution at once, the vat should be partly filled with water and then the arsenical solution added as it is made. For example, if the vat holds 2000 gallons, about 1500 gallons of water should be placed in the vat, then four times the amount of solution for making 500 gallons of dip should be prepared and mixed with the water, after which the vat should be filled to the 2000-gallon mark. Within certain limits it is immaterial just how much water is added at first, provided, of course, ample allowance is made for the volume of the concentrated dip so that when it is added the dip line will not come above the mark to which the vat is to be filled.

"The capacity of the vat at a depth of 5 feet 3 inches is 1470 gallons. In order to fill it to that depth with dip it will be necessary to prepare two batches of concentrated dip, each containing the ingredients necessary for making 500 gallons of diluted dip, and a third batch containing 7 pounds, 9 ounces of arsenic and 22 pounds, 3 ounces of sodium carbonate in case 8 pounds of arsenic are being used to the 500 gallons, or 9 pounds, 7 ounces of arsenic and 22 pounds, 8 ounces of sodium carbonate in case 10 pounds of arsenic are being used to the 500 gallons.

"The arsenical dip may be left in the vat and used repeatedly, replenishing it with the proper quantities of water and stock solution when necessary. When, however, the dip becomes filthy through the addition of manure and dirt carried in by the cattle, the vat should be emptied, cleaned, and filled with fresh fluid. The frequency with which this should be done must be left to the owner, as the condition of the dip at any period after it has been made depends on a variety of conditions, such as the number of cattle dipped, and the frequency of the dippings, etc. Even though the dip may not become very filthy, its efficiency decreases somewhat on standing, owing to gradual oxidation of the arsenic. It is therefore advisable to recharge the vat at intervals irrespective of the condition of the dip to cleanliness."

Precautions. — From the time the arsenic is purchased to the final disposal of the old dip, great care should be exercised in storing, handling and using the same owing to the very poisonous nature of the chemical. "Cattle should always be watered a short time before they are dipped. After they emerge from the vat they should be kept on a draining floor until the dip ceases to run from their bodies; then they should be placed in a yard free of vegetation until they are entirely dry. If cattle are allowed to drain in places where pools of dip collect from which they may drink, or are turned at once on the pasture, where the dip will run from their bodies on the grass and other vegetation, serious losses are liable to result. Crowding the animals before they are dry should also be avoided, and they should not be driven any considerable distance within a week after dipping, especially in hot weather. If many repeated treatments are given, the cattle should not be treated oftener than every two weeks.

"In addition to properly protecting vats containing arsenical dip when not in use another precaution must be observed when vats are to be emptied for cleaning. The dip should not be poured or allowed to flow on land and vegetation to which cattle or other animals have access. The best plan is to run the dip into a pit properly protected by fences. The dip should also not be deposited where it may be carried by seepage into wells or springs which supply water used on the farm."

Procedure. — After having exercised the precaution of watering them, the cattle to be dipped are driven from a pen one by one into the chute and thence into the dip (Fig. 192). The plunge is likely to wet the animal all over, but a second plunge of the head into the dip near the middle of the vat by means of a forked stick is advised so that the head is really plunged under twice in passage through the dip. After drying, the cattle should be driven on to a tick-free pasture and the process repeated in from seven to ten days in order to destroy all ticks which may have escaped the action of the first dipping.

Pasture Rotation. — Exterminating ticks by pasture rotation is based on the time required to kill the ticks by starvation. Inasmuch as the longevity of ticks depends on moisture and temperature mainly, local conditions affecting the same must be taken into consideration. Cold and moisture prolong life, while dryness and heat shorten the same.

In pasture rotation the cattle are kept off of a given pasture for a given length of time, after which they are moved to a third area, etc., until all ticks have matured and have dropped from the cattle and have died from starvation on the earlier plots. Thus a field should be divided into three or more plots each separated by means of two fences about fifteen feet apart to reduce the opportunity of ticks to crawl from one plot to the other.

Various plans requiring from four and a half to eight months have been devised to free both cattle and pasture from ticks. Thus a plan requiring four and one half months is described by Graybill (1912, *loc. cit.*) (Fig. 193). He advises dividing the pasture in the middle by two

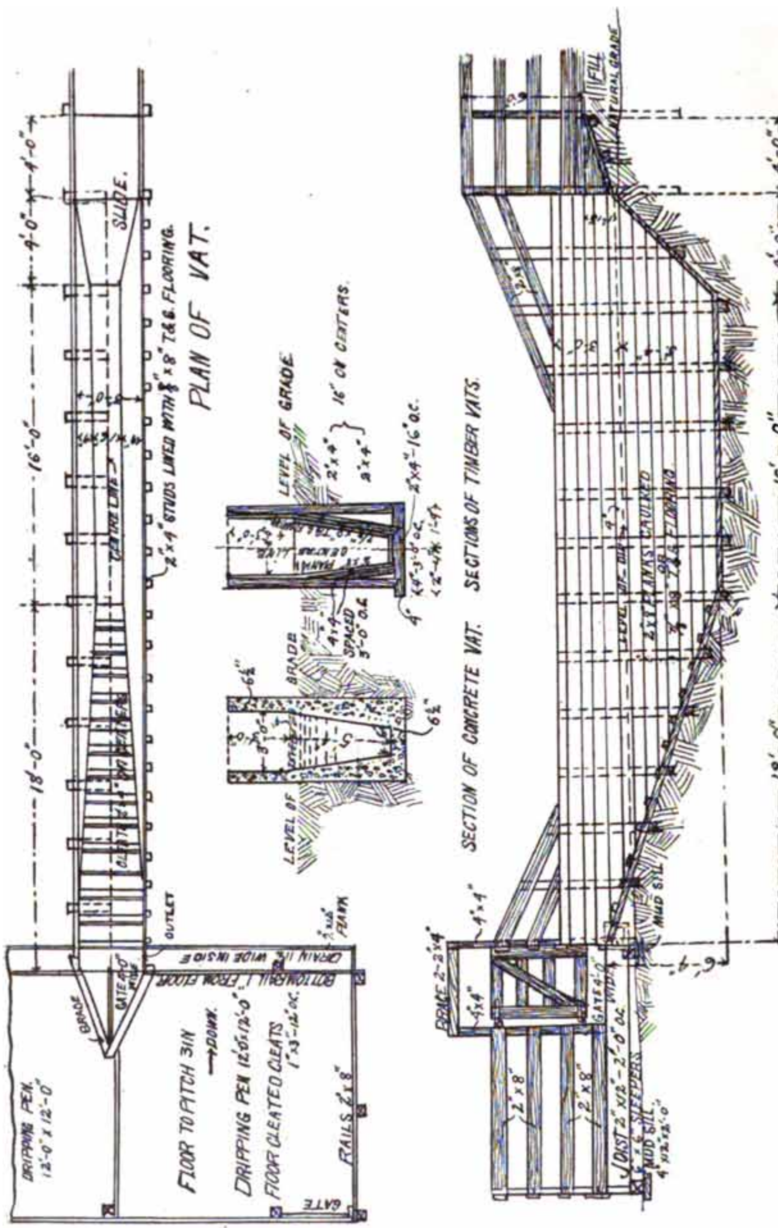

FIG. 192. — Drawings for wood or concrete dipping vat. (Redrawn after Graybill.)

lines of temporary fence fifteen feet apart. This to be done some time in the spring. The herd is first kept in field No. 1A, and is then removed, on June 15, to field No. 1B, and on September 1 to field No. 2A. The cattle must remain twenty days on fields 2A, 2B, and 3. At the end of this time, which would be November 1, all the ticks will have dropped and the herd is returned to field No. 1A, which has become free from ticks in the meantime. Field No. 1B becomes free from ticks July 1 of the following year, when the double fence between 1A and 1B may be removed and the cattle may then (and not before) graze over both fields. By August 1 the entire farm will be free from ticks.

Graybill advises as above that double fences be built between all the fields, when practicable, in order to prevent ticks from getting from one field to another. In place of the extra line of fence the next best thing would be to "throw up several furrows with a plow on each side of the dividing fences." If streams run through the farm or the slope of the land is considerable, so that ticks may be washed from field to field, he advises arranging the fields so that drainage is from field No. 1A to No. 1B, and from No. 3 toward fields Nos. 2A and 2B.

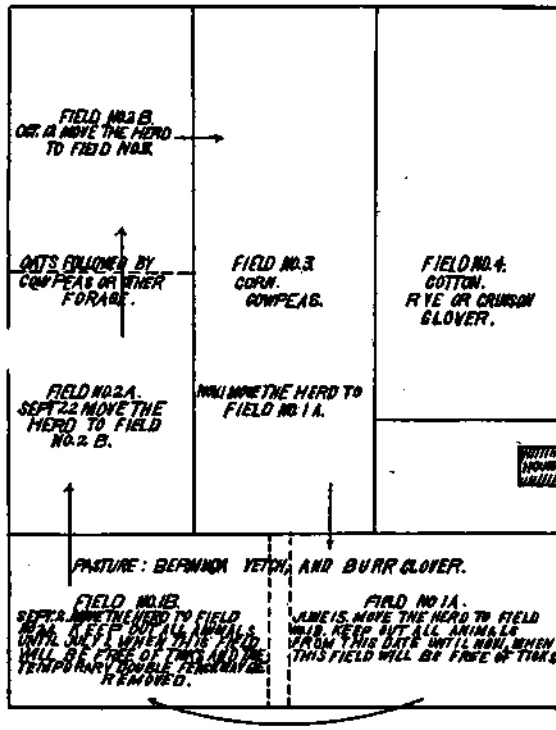

Fig. 193. — Plan for freeing cattle and pastures from ticks by rotation, requiring four and one half months. (Redrawn after Graybill.)

African coast fever, also known as Rhodesian red water, occurs along the east coast of Africa, including Rhodesia and the Transvaal. The mortality is said to range close to 90 per cent. The causative organism is *Theileria parva* (Theiler). The symptoms of the disease, according to Robertson,[1] are described as follows: "These are

[1] Robertson, W., 1904. African coast fever. Cape of Good Hope, Dept. of Agr. Bull. 18.

neither very definite nor characteristic. The disease runs its course in from twelve to fifteen days, dating from the time the animal is first noticed sick. The temperature is high, 106° to 107° F. There is running from the eyes and nose, and symptoms of pain in the abdomen. Purging and diarrhea are frequently seen. In the later stages the dung may contain blood and be dark in color. The animal's brain usually becomes affected before death, which is preceded by stupor and coma. If the lungs become involved there is great distress in breathing, accompanied by a short cough." Lounsbury's[1] experiments demonstrate that African coast fever may be transmitted to susceptible cattle from actually sick ones through the medium of five species of ticks of the genus Rhipicephalus, namely *R. appendiculatus*, *R. evertsi*, *R. simus*, *R. capensis*, and *R. nitens*. He succeeded in transmitting the disease from twelve sick animals to thirty-five healthy ones by means of ticks. The infection was taken by ticks in one stage of the life history and transmitted in the next following stage. A dozen or more ticks were usually applied in each case; however he succeeded in infecting an animal with one tick alone and in another case by two ticks. The ticks are believed to be in constant readiness to transmit infection. The incubation period was found to average thirteen and one-half days and ranged from nine to nineteen days. While the duration of the cases averaged twelve days, it was found that few of the animals appeared seriously ill until a few days before death, an important factor in the dissemination of the disease in the veldt during the time that the infective animal is active.

Other important discoveries were that the disease did not result from ticks fed on recovered animals, neither from the progeny of ticks from sick animals, nor from adults which as nymphs had fed on immune animals, but as larvæ had fed on sick animals.

Spotted Fever. — Spotted fever has been known in the Bitter Root Valley of Montana (U. S. A.) since 1872,[2] also known as "tick fever," "black fever," "blue disease," "black measles," and "*piroplasmosis hominis*." The causative organism is doubtfully referred to as *Piroplasma hominis* (Wilson and Chowning). The most characteristic and constant symptom is the eruption which appears about the second to the fifth day on the wrists, ankles and back, later spreading to all parts of the body and lasting from a few days (8 to 21) to several months: "These spots are petechial and not raised; at first they are rose-colored and disappear momentarily upon pressure; but later they become permanent and assume a dark blue or purplish color; they may coalesce and give a mottled or marbled appearance to the skin; they may or

[1] Lounsbury, Chas. P., 1906. Ticks and African coast fever. Agric. Journ. of the Cape of Good Hope, Vol. XXVIII, No. 5, pp. 634–654.

[2] Stiles, Ch. Wardell, 1905. A zoölogical investigation into the cause, transmission and source of Rocky Mountain "spotted fever." Treasury Dept. Public Health and Marine Hospital Service of the United States. Hygiene Lab. Bull. No. 20, pp. 121.

may not be tender to the touch. . . . The fever develops rapidly, and may register 102° to 104° or 105° F., when the patient takes to bed. It gradually reaches its maximum in two to seven days, when it ordinarily registers 103° to 106°.

"Both sexes and all ages are subject to the disease, but it is more common in males from 21 to 40, and in females from 11 to 40 years of age, than at other times of life. . . . A lethality of 70.5 per cent was shown for 139 collated cases . . . 100 per cent for all patients over 60 years old. So far as one could judge occupation seems to play a rôle, for a very large percentage of the patients are on farms or are connected with the lumbering industry" (Stiles, 1905, *loc. cit.*).

In Idaho a mild type of the disease exists, with a mortality of about 1 to 3 per cent according to Stiles and from 5 to 7 per cent according to Hunter and Bishopp.

Tick Transmission of Spotted Fever. — After a preliminary investigation Wilson and Chowning [1] in 1902 advanced for the first time the theory that a tick ("wood tick") acts as the natural vector of the disease. According to Rickette (in 48th Biennial Rept. Montana State Board of Health, p. 106) as recorded by Hunter and Bishopp [2] "the first experiments which resulted in the proof of the transmission of spotted fever by a tick were conducted by Doctors McCalla and Brereton of Boise, Idaho, in 1905. In these experiments a tick which was found attached to a spotted fever patient was removed and allowed to bite a healthy person. In eight days this person developed a typical case of spotted fever. The experiment was continued by allowing the same tick to bite a second person. In this case again a typical case of spotted fever resulted."

The famous experiments of Doctor H. T. Ricketts began in April, 1906. The more important published work of this lamented investigator has been brought together in a memorial volume [3] from which the following summary is made of his reports on spotted fever. First of all it was shown that the disease could be transmitted to guinea pigs by direct inoculation and that the duration of the fever and cutaneous phenomena resembled very closely the conditions as observed in humans. Hence, knowing the susceptibility of this species, it was used for further experimentation.

On June 19, 1906, a small female tick was placed at the base of the ear of a guinea pig inoculated intraperitoneally June 11 with 3 cc. of defibrinated blood of a spotted fever patient. The tick fed for two

[1] Wilson, Louis B., and Chowning, William M., 1902. The so-called "spotted fever" of the Rocky Mountains. A preliminary report to the Montana State Board of Health. Journ. Amer. Med. Assoc., Vol. 39, No. 3, pp. 131–136.

[2] Hunter, W. D., and Bishopp, F. C., 1911. The Rocky Mountain spotted fever tick. U. S. Dept. of Agric., Bur. of Ento. Bull. 105, pp. 47.

[3] Ricketts, H. T., 1911. Contributions to Medical Science. The University of Chicago Press. 497 pp. (See pp. 278–450.)

days on this animal and was then removed and kept for two days in a pill box and on June 23 placed at the base of the ear of a healthy guinea pig, the former animal dying on the same day with characteristic symptoms. On June 28 the second guinea pig showed a decided rise in temperature, which continued high until July 5 and became normal on July 7. Proper controls were conducted and two guinea pigs which were in the same cage with the tick-bitten guinea pig for two weeks did not become infected, indicating that mere association did not result in contracting the disease.

In addition to many other successful experiments during the following year Ricketts found that the disease can be transmitted by the male as well as by the female tick and that "one attack of the disease establishes a rather high degree of immunity to subsequent inoculation." Furthermore a collection of ticks taken in the field transmitted the disease to a guinea pig in the laboratory, indicating the fact that infective ticks occur in nature in probably small numbers.

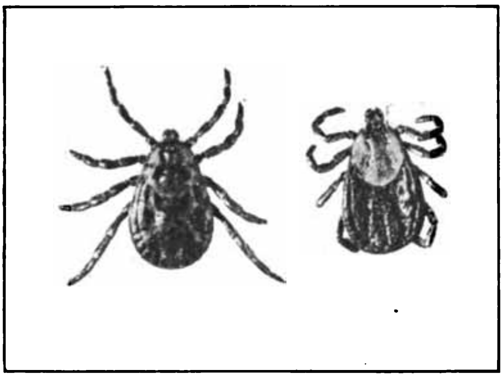

FIG. 194. — The spotted fever tick, *Dermacentor venustus;* male (left), unengorged female (right). × 3.5.

It was also ascertained that "the disease may be acquired and transmitted . . . by the tick during any of the active stages . . . and that the larvæ of an infected female are in some instances infective. . . . The disease probably is transferred through the salivary secretion of the tick, since the salivary glands of the infected adult contain the virus." The transmission is believed to be "biological rather than purely mechanical."

Experiments conducted by Moore (Ricketts, 1911, *loc. cit.*, pp. 428–436) show that the "minimum duration of feeding necessary for a tick to infest a guinea pig was one hour and forty-five minutes. The average time necessary seems to be about ten hours, while twenty hours were almost constantly infective." Maver (see Ricketts, 1911, *loc. cit.*, pp. 440–444) in a series with other species of ticks found that spotted fever can be transmitted from infected to normal guinea pigs by *Dermacentor variabilis, Dermacentor marginatus* and *Amblyomma americanum,* in addition to *Dermacentor venustus.*

Ricketts' careful observations with regard to the causative organism failed to substantiate the findings of Wilson and Chowning that the disease is of piroplasmic origin, although he failed to secure infective virus by passing serum diluted tenfold in physiologic salt solution through a Berkefeld filter. This he states " suggests that the organism, though undoubtedly minute, is of such size that it should be recognized by the use of high magnifications, or that it is of peculiar form or possesses such adhesive properties that it is not readily filterable."

Rocky Mountain Spotted Fever Tick. — The spotted fever tick, *Dermacentor venustus* Banks (Fig. 194), possesses the general characters of the genus Dermacentor, viz., " Usually ornate, with eyes and festoons; with short, broad or moderate palps and *basis capituli* rectangular dorsally. In some species coxæ I to IV of the male increase progressively in size; in all species coxa IV is much the largest; the male, moreover, shows no ventral plates or shields. Coxa I bifid in both sexes. Spiracles sub-oval or comma-shaped " (Nuttall, 1911, *loc. cit.*).

The species is described by Banks,[1] viz.:

"Male — red brown, marked with white, but not so extensively as in *D. occidentalis*, usually but little white on the middle posterior region; legs paler red-brown, tips of joints whitish. Capitulum quite broad, its posterior angles only slightly produced; palpi very short and broad, not as long as width of capitulum. Dorsum about one and two-thirds or one and three-fourths times as long as broad, with many, not very large, punctures; lateral furrows distinct. Legs of moderate size, hind pair plainly larger and heavier, and with the teeth below distinct. Coxæ armed as usual, the coxa IV nearly twice as wide at base as long. Stigmal plate with a rather narrow dorsal prolongation, with large granules on the main part and minute ones on the prolongation.

"Length of male, 3.5 to 5 mm.

"Female — Capitulum and legs reddish brown, the latter with tips of joints whitish; shield mostly covered with white, abdomen red-brown. Capitulum rather broad, posterior angles but little produced, the porose areas rather large, egg-shaped, and quite close together; palpi shorter than width of capitulum. Shield as broad as long, broadest slightly before the middle, and rather pointed behind, with numerous, not very large punctures. Legs of moderate size, the coxæ armed as usual. The stigmal plate has a rather narrow dorsal prolongation, with large granules on the main part, and small ones on the prolongation.

"Length of female shield, 2 mm."

Life History and Habits of Spotted Fever Tick. — The most complete and satisfactory study of the habits and life history of this species has been made by Hunter and Bishopp (*loc. cit.*), from whose work the following account is taken. The winter is passed by the ticks as unengorged males, females and nymphs. They begin attacking their warm-blooded hosts, including man, about March 15 and continue so doing to about July 15. During this period the female deposits eggs. The overwintering nymphs transform to adults during the summer and autumn and pass the winter in an unengorged condition, thus requiring about two years for their development. As much as three years may be required for complete development under unfavorable conditions.

The engorged females after being fertilized drop from the host

[1] Banks, Nathan, 1908. A Revision of the Ixodoidea, or Ticks, of the United States. U. S. Dept. of Agr. Bur. of Ento. Technical Series, No. 15, 61 pp.

animal and deposit about 4000 eggs within thirty days, beginning to deposit as early as the seventh day after dropping. The eggs are ovoid, brownish in color and about one thirty-eighth of an inch long. The incubation period ranges from thirty-four to fifty-one days in the Bitter Root Valley (15–41 days at Dallas, Texas). The newly emerged hexapod seed ticks shortly after hatching crawl up blades of grass or other objects and await the coming of a host, usually one of the smaller species of rodents, *e.g.* ground squirrels, chipmunks, woodchucks, pine squirrels and wood rats.

After attaching to the host the larvæ become filled with blood in from three to eight days, after which they drop off and molt in from six to twenty-one days, emerging from this stage with eight legs, — a nymph. Nymphs emerging from the larval or seed tick stage late in summer or autumn pass the winter as nymphs, others find a second host, either a small mammal or less commonly a larger wild or domesticated animal. The feeding period requires from four to nine days, when the engorged nymphs drop to the ground and in twelve to sixteen days and over, molt for the second time, emerging as adults.

The adults now by preference attach themselves to larger domesticated animals. After feeding about four days the males search their mates, mating on the host animal, and after eight to fourteen days after attachment the engorged females drop to the ground and deposit their eggs in some protected place near by. The life cycle requires two years in the majority of cases; however, in some one season is sufficient.

The fully engorged females are "about one half inch long by one third inch wide by one fourth inch thick. On account of the enormous distention of the back part of the body of the female, the legs and head are rendered inconspicuous. A close examination, however, will show the white shield on the back just behind the 'head.'" The males are about the same size as the females before engorgement, and have the shield (scutum) covering the entire back, whereas in the female the shield is much smaller (Fig. 194).

Longevity. — Hunter and Bishopp (1911, *loc. cit.*) have "found that all unfed seed ticks hatching from a mass of eggs usually die within one month after the first eggs hatch. In one instance a period of 117 days elapsed between the beginning of hatching of the eggs and the death of the last seed tick. (A later record by these workers exceeded 317 days.) Unfed nymphs have been found to survive a period of one year and eleven days, and adults collected on vegetation during the spring months may survive for a period of 413 days without food."

Distribution. — Bishopp[1] states that the northern part of the Rocky Mountain region of the United States is the territory principally infested, but the river valleys and sagebrush plains in the west are more or less heavily infested, — Idaho, Wyoming, Montana, parts

[1] Bishopp, F. C., 1911. The Distribution of the Rocky Mountain Spotted-fever Tick. U. S. Dept. of Agr., Bur. of Ento. Circ. No. 136.

of Utah, Colorado, Nevada, Oregon, Washington, California and southern British Columbia being involved. The species is believed to occur in greatest numbers between 3000 and 5000 feet.

Control of Spotted Fever Tick.—Knowing that the most important agent, if not the sole agent under natural conditions, in the dissemination of spotted fever is *Dermacentor venustus*, it becomes evident at once that the control of this tick is essential to the control of the disease.

Since the principal hosts for the adult stage of the tick are the larger domesticated animals, principally horses and cows, these animals must be kept free from ticks by the application of ordinary tick control measures (see under Texas fever). Because the tick requires at least two years to complete its life history, domesticated animals must be kept free from ticks for at least two consecutive years. In this way maturity is prevented and no eggs will be deposited to furnish a new supply of seed ticks to feed on smaller rodents. No doubt also much exterminative work must be done against the smaller rodents, as well as the larger wild animals.

The most significant step toward the control of spotted fever in Montana was taken by the legislature of that state in 1913, when a bill was passed creating a State Board of Entomology, with authority to act, and appropriating $5000 per annum for its use during a period of two years. The act seems so significant that it is here given in full:

"An Act to Create the State Board of Entomology. To define its powers and duties and appropriate money therefor.

"Be it enacted by the Legislative Assembly of the State of Montana.

"*Section* 1. There is hereby created the Montana State Board of Entomology, which shall be composed of the State Entomologist, the Secretary of the State Board of Health and the State Veterinarian.

"*Section* 2. The Secretary of the State Board of Health shall be Chairman of said Board and the State Entomologist shall be Secretary.

"*Section* 3. None of the members of said Board shall receive any compensation other than that already allowed by law, except that the actual expense of members while engaged in the duties incident to the work of said board shall be paid out of the appropriation made to carry on the work of said board.

"*Section* 4. It shall be the duty of said board to investigate and study the dissemination by insects of diseases among persons and animals, said investigation having for its purpose the eradication and prevention of such diseases.

"*Section* 5. Said board shall take steps to eradicate and prevent the spread of Rocky Mountain tick fever, infantile paralysis and all other infections or communicable diseases that may be transmitted or carried by insects.

"*Section* 6. Said board shall have authority to make and prescribe rules and regulations including the right of quarantine over persons and animals in any district of infection and shall have the right to designate and prescribe the treatment for domestic animals to prevent the spread of such diseases; but said board shall not have the right to prescribe or regulate the treatment given to any person suffering from any infectious or communicable disease.

"*Section* 7. All rules and regulations of the State Board of Entomology shall be subject to approval by the State Board of Health.

"*Section* 8. The board shall publish in printed form all rules and regulations which shall be adopted by said board for the eradication and control of diseases of any kind and such rules and regulations shall be circulated among the residents of every district affected thereby.

"*Section* 9. Any person who shall violate any of the rules or regulations of the State Board of Entomology shall be deemed guilty of a misdemeanor and upon conviction thereof shall be fined in any sum not in excess of one hundred ($100.00) dollars, or by imprisonment in the County Jail for any period not exceeding thirty (30) days or by both such fine and imprisonment.

"*Section* 10. There is hereby appropriated out of any moneys in the State Treasury not otherwise appropriated the sum of five thousand ($5000.00) dollars, or so much thereof as may be necessary to carry on the work of the State Board of Entomology for the year 1913, and the sum of five thousand ($5000.00) dollars or so much thereof as may be necessary to carry on the work of said board for the year 1914. Said money to be expended under the direction and approval of the State Board of Examiners.

"*Section* 11. All Acts or parts of Acts in conflict with this Act are hereby repealed.

"*Section* 12. This Act shall take effect from and after its passage and approval.

"Approved March 18, 1913."

Other Piroplasmoses. — At least two types of piroplasmoses are found in horses and mules, namely true equine piroplasmosis, traceable to *Babesia caballi* (Nuttall), occurring in Russia, Transcaucasia and probably Siberia, and secondly a similar though distinct disease traceable to *Nuttallia equi* (Laveran) occurring in Transcaucasia, Italy, Africa, India and South America (Brazil). The former is transmitted by *Dermacentor reticulatus* while the latter is transmitted by *Rhipicephalus evertsi.*

Ovine piroplasmosis traceable to *Babesia ovis* (Babes) occurs in sheep in Transcaucasia, Roumania, Turkey and probably also in northern Africa. The disease is carried by the tick, *Rhipicephalus bursa.*

Canine piroplasmosis, also known as " malignant jaundice " of dogs, is prevalent in Europe, Asia and Africa. The causative organism is *Babesia canis* Piana and Galli-Valerio and the carrier is *Rhipicephalus sanguineus* in India, Europe and North Africa; *Hæmaphysalis leachi* is the carrier in other parts of Africa.

Tick Paralysis. — A very striking form of paralysis induced by the bite of *Dermacentor venustus* has been reported [1] as occurring in both sheep and man (children), also in other animals (dog and rabbit), in British Columbia and Montana. In lambs the paralysis develops gradually, beginning with a staggering gait, bumping against obstacles and occasionally falling, finally failing to rise. The attack is usually of short duration but may persist for long periods and may terminate fatally. The symptoms appear in from six to seven days after the ticks have become attached. It is believed that the disease is caused by the

[1] Hadwen, Seymour, 1913. On "Tick paralysis" in sheep and man following bites of *Dermacentor venustus*. Parasitology, Vol. VI, No. 3, pp. 293–297, with 2 plates.

inoculation of a toxin from the tick. It has also been observed that the ticks attach themselves by preference along the spinal column of the host, and at the nape of the neck in man.

Other Ixodine Ticks. — Over forty species of ticks (mostly Ixodine) are known to occur in the United States alone, and many other species occur in the tropics. For the disease-bearing and venomous species it may be said that a single individual may be of great importance, while the economic importance of the innocuous species depends on relative abundance. The most widely distributed and abundant genera are Ixodes and Dermacentor. *Ixodes ricinus* Linn., commonly called the "castor bean tick," is found in Europe, America, Asia and Africa, and attacks many species of warm-blooded animals. *Ixodes ricinus* var. *californicus* Banks (Fig. 195) is commonly found in California on the black-tailed deer, the bobcat and other species of wild animals, also frequently and abundantly on cattle. The common "dog tick" or "wood tick" also attacks many species of warm-blooded animals, among them horses, cattle, dogs and man. When abundant these species are of considerable importance. In the eastern part of the United States *Dermacentor variabilis* Say is the most common, while along the Pacific Coast it is largely replaced by *Dermacentor occidentalis* Neumann (Fig. 196). In the southern part of the United States, particularly Texas and Louisiana, the "lone star tick," *Amblyomma americanum* Linn. (Fig. 197) is very common. The "rabbit tick," *Hæmaphysalis leporis = palustris* Packard, is a widely distributed and abundant species on rabbits, while *Rhipicephalus sanguineus* Latreille is known as the "brown dog tick" and is almost a cosmopolitan species.

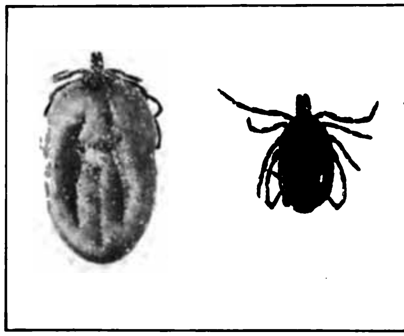

Fig. 195. — A common deer and cattle tick of California, *Ixodes ricinus* var. *californicus*; female (left), male (right). × 3.5.

Fig. 196. — Western dog or wood tick, *Dermacentor occidentalis*. × 2.5.

Nuttall (1911, *loc. cit.*) includes nine genera in the family Ixodidæ, namely: — Ixodes, Hæmaphysalis, Dermacentor, Rhipicentor, Rhipicephalus, Margaropus, Boöphilus, Hyalomma and Amblyomma (Apǫnomma). "Ixodes is clearly marked off from the other genera by a number of characteristics, of which the most striking are the anal groove surrounding the anus *in front* (Prostriata) and the absence of festoons. The remaining genera fall naturally into two divisions: the one characterized by a comparatively short, and the other by a comparatively long, capitulum." Nuttall further arranges these as follows:

- Ixodidæ
  - Prostriata
    - 1 Ixodes
  - Metastriata
    - Brevirostrata
      - Group 1
        - 2 Hæmaphysalis
      - Group 2
        - 3 Dermacentor
        - 4 Rhipicentor
        - 5 Rhipicephalus
        - 6 Margaropus
        - 7 Boöphilus
    - Longirostrata
      - Group 1
        - 8 Hyalomma
      - Group 2
        - 9 Amblyomma

"**Ixodes**: inornate; without eyes and without festoons; spiracles round or oval; palpi and basis capituli of variable form; coxæ either unarmed, trenchant, spurred or bifid; tarsi without spurs. Sexual dimorphism pronounced, especially with regard to the capitulum; in the male the venter is covered by non-salient plates; one pregenital, one median, one anal, two adanal and two epimeral plates."

"**Hæmaphysalis**: inornate, without eyes but with festoons; with usually short conical palpi whose second articles project laterally beyond the basis capituli, which is rectangular dorsally. With dorsal process on first trochanter. Usually of small size and but slightly chitinized. Sexual dimorphism slight. The male shows no ventral plates or shields. Spiracles in male usually ovoid or comma-shaped; in female rounded or ovoid."

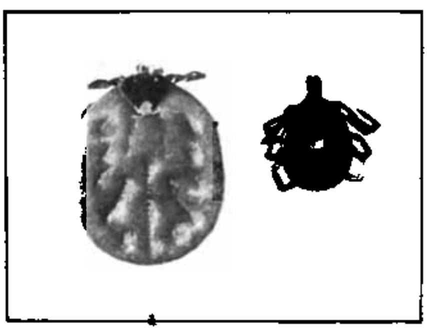

FIG. 197. — The lone star tick. *Amblyomma americanum.* × 3.5.

"**Dermacentor**: usually ornate, with eyes and festoons; with short, broad or moderate palpi and basis capituli rectangular dorsally. In some species coxæ I to IV of the male increase progressively in size; in all species coxa IV is much the largest; the male, moreover, shows no ventral plates or shields. Coxa I bifid in both sexes. Spiracles suboval or comma shaped."

"**Rhipicentor**: inornate, with eyes and festoons; with short palpi, with basis capituli hexagonal dorsally and having very prominent lateral angles. Coxa I bifid in both sexes. The male resembles *Rhipicephalus* dorsally, *Dermacentor* ventrally; coxa IV is much the largest; no ventral plates or shields; spiracles subtriangular (female) or comma-shaped (male)."

"**Rhipicephalus**: usually inornate, with eyes and festoons; with short palpi and basis capituli usually hexagonal dorsally. . . . Coxa I bifid. The male possesses a pair of adanal shields and usually a pair of accessory adanal; some males, when replete, show a caudal protrusion. Spiracles bluntly or elongate comma-shaped."

"**Margaropus**:[1] inornate, with eyes, but without festoons, with short palpi and capitulum intermediate between that of *Rhipicephalus* and *Boöphilus;* highly chitinized, the unfed adults of large size. The female with very small scutum. Coxæ conical, unarmed but for a small spine posteriorly on coxa I. The male with a median plate prolonged in two long spines projecting beyond and to either side of the anus; with coxæ similar to those of the female; legs increasing progressively in size from pair I to IV, the articles especially of leg-pair IV greatly swollen. When replete, the male shows a caudal protrusion. Anal groove obsolete. Spiracles rounded or short-oval in both sexes."

"**Boöphilus**: inornate, with eyes, but without festoons; with very short compressed palpi ridged dorsally and laterally; basis capituli hexagonal dorsally; slightly chitinized; the unfed adults of small size. Coxa I bifid. Anal groove obsolete in female, faintly indicated in male. The female with a small scutum; the male with adanal and accessory adanal shields. Spiracles rounded or oval in both sexes."

"**Hyalomma**: ornamentation absent or present, at times confined to the legs; with eyes, with or without festoons, with long palpi . . . and basis capituli subtriangular dorsally. The female approaching *Amblyomma*. The male with a pair of adanal shields, and with or without accessory adanal shields and two posterior abdominal protrusions capped by chitinized points. Coxa I bifid. Spiracles comma shaped."

"**Amblyomma**: generally ornate, with eyes and with festoons. With long palpi, of which article 2 is specially long; basis capituli of variable form. The male without adanal shields, but small ventral plaques are occasionally present close to the festoons. Spiracles subtriangular or comma-shaped" (Nuttall).

The Argasine Ticks

Agas persicus Oken = A. miniatus Neumann = A. americanus Packard, a cosmopolitan *fowl tick,* is one of the most important poultry parasites in existence (Fig. 198). Other than "fowl tick" this pest is commonly called "adobe tick" or "tampan." In color it varies from a light reddish brown to a dark brown, depending on the stage of engorgement. In size the obovate, flattened adults average about 8.5 mm. long by 5.5 mm. wide in the female, and 6.5 mm. long by

[1] Does not include *Margaropus annulatus* = *Boöphilus annulatus.*

Y

4.5 mm. wide in the male. When unengorged their thickness is about .75 mm., and when fully engorged may be nearly 3 mm. at the thickest part. The edges are always very thin even when engorged. The sexes are not easily distinguishable; the males are smaller, but may be as large as smaller female individuals, and taper slightly more anteriorly, *i.e.* are more obovate. The genital orifice of the male is "half-moon shaped," while in the female it is "slit-like" and situated farther forward, *i.e.* immediately behind the capitulum. The capitulum has four long hairs, two hypostomal, and one near the articulation of each palp, all directed forwards. The palps are about twice as long as the hypostome, second article longest, the others equal in length. The hypostome has 6 or 7 fine denticles on each half distally, followed by stout teeth $\frac{2}{2}$, the numbers increasing to $\frac{3}{3}$, $\frac{4}{4}$, $\frac{5}{5}$, basally, the teeth decreasing in size, not attaining the external border nor extending beyond half the length of the hypostome (Nuttall).

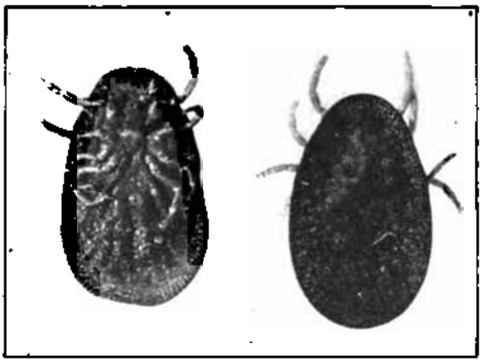

Fig. 198. — The poultry tick, *Argas (miniatus) persicus*, ventral and dorsal views. × 3.5.

Life history and habits. — The nymphs and adults of *Argas persicus* are strikingly active at night, migrating long distances to find their host, and hiding in an inactive condition during the day. The writer has observed this pest in vast numbers hiding beneath the loose bark of the eucalyptus tree in California. Occasionally specimens are sent in with the inquiry, "are they parasites of the tree or do they attack roosting chickens, the chickens seem to do very poorly, yet we find nothing on them?" At night if one observes somewhat closely, one may see hordes of these ticks climbing up the sides of the chicken coop to the roosts and upon the fowls, filling up leisurely with blood and before daybreak departing for their hiding places. The females deposit their large reddish brown eggs in the crevices occupied during the day. The eggs are laid in masses of from 25 to 100, more or less, and there are usually several layings,

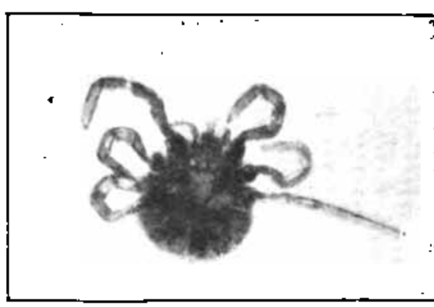

Fig. 199. — Larva of the poultry tick, *Argas (miniatus) persicus*. × 30.

once after each meal. Egg deposition occurs very readily in almost any sort of receptacle in which the ticks may be kept for observation. Hatching takes place in from three to four weeks. The larvæ (Fig. 199) are six-legged and very active, attacking a host apparently as readily by day as by night. Once attached the larvæ feed for about five days, occasionally longer, remaining firmly attached during this time. When fully engorged they appear like little reddish globules, causing severe irritation. At the end of this feeding period the larvæ detach themselves, having become rather flattened in the meantime and then crawl away from the host, hiding in some convenient crevice near by. The larvæ molt in about a week, when the fourth pair of legs appears and they are now in the first nymphal stage, appearing like miniature adults. Nocturnal feeding now takes place and in ten or twelve days another molt occurs and the second nymphal stage is reached. Again the tick attaches itself, being now able to engorge itself in about an hour; again after the expiration of something over a week a third molt takes place and the adult stage is reached. The adults are able to engorge themselves in from 20 to 45 minutes.

Since eggs are deposited mainly during July in California, the adult stage may or may not be reached before the rainy season begins, and the overwintering stage may be in the second nymphal condition or as adults, appearing in pestiferous numbers early during the following summer. Hence there is ordinarily one generation of ticks per year under normal conditions. In the absence of a host this species manifests a striking longevity of a year and over (a little over two years according to Lounsbury).

Damage Done. — Each tick when engorging requires considerable blood to become replete, hence, when myriads of these parasites attack fowls great quantities of blood must be extracted. The writer has known of chickens being picked up under the roost in the morning with no apparent cause for death, and believes this to have been due directly to the work of ticks. Weakened and unthrifty condition of a flock may be traceable solely to ticks. Poultry suffering from ticks have dull, ragged plumage, suffer from diarrhea, are weak and lay poorly.

Fowl Spirochætosis. — A very fatal disease, known as "fowl spirochætosis," is traceable to *Spirochæta marchouxi* Nuttall = *Spirochæta gallinarum* Blanchard, occurring in India, Australia, Brazil, Egypt and Persia, and is no doubt very widely distributed. The disease attacks chickens, geese, turkeys, guinea fowls and other birds. The symptoms are described as follows:

"The disease begins with diarrhea, followed by loss of appetite, the birds appearing somnolent; the feathers being ruffled and the comb pale. The birds cease to perch, lie down with the head resting upon the ground and death takes place during a convulsive attack. At times the disease runs a slower course, the legs become paralyzed, then the wings, and the bird grows thin and dies in eight to fifteen days.

Recovery may take place, but it is rare after paralytic symptoms have appeared. At autopsy, during the acute period of the disease, the spleen appears much enlarged and the liver swollen with more or less fatty degeneration, at times the liver is dotted with focal necroses. In chronic cases both these organs may appear atrophied. The blood is fluid and dark. Spirochætes are plentiful in the blood until shortly before death, and they disappear as recovery sets in" (Nuttall).

Argas persicus has been proved to be the carrier by Marchoux and Salimbeni, Balfour, Nuttall and others. These investigators have found that when this tick sucks blood from an infected fowl the *spirochætes* multiply within the body of the same when kept at from 30° to 35° C. and are capable of transmitting the disease; but when they are kept at from 15° to 20° C. they fail to transmit it. However, if the ticks are later kept in the higher temperature they become infective. The *spirochætes* are transmitted by the bite and the ticks are said to be infective for six months or more. The incubation period in the fowl is from four to nine days.

Combating the Fowl Tick. — Henhouse roosts should be painted thoroughly with kerosene or gasoline and put in position with the ends in cups of crude oil or tar or embedded in oil-soaked waste, or suspended by wires from the ceiling. Roost poles must be free from bark. All old nests and rubbish should be burned, and the interior, especially crevices, sprayed liberally with kerosene. Boiling water or steam may be used instead of kerosene. A repetition of the procedure once every five or six weeks during the tick season is recommended. The use of considerable crude oil in and about the houses is very desirable. Fowls should not be permitted to roost in trees, because of the hiding places afforded the ticks beneath the bark, particularly when loose.

If the henhouses can be made tight, fumigation with sulphur is useful, using about five pounds per 1000 cu. ft. of space.

For the treatment of fowls infested with larval ticks, an ointment of kerosene, lard and sulphur is advised.

Argas reflexus Fabr., commonly known as the "pigeon tick," differs from *A. persicus* in that the body narrows rather suddenly toward the anterior end and that the thin margin is flexed upward. The capitulum has "two long post-hypostomal hairs ventrally, directed forwards. Palps with articles sub-equal, the third the shortest, denticulated hairs dorsally. . . . Hypostome rounded terminally, some small denticles at the tip, followed by $\frac{2}{2}$ stout teeth merging into $\frac{3}{3}$ to $\frac{6}{6}$ progressively smaller teeth" (Nuttall).

Other species of Argas are *A. brumpti* Neumann, *A. vespertilionis* Latreille and *A. cucumerinus* Neumann.

Ornithodorus moubata Murray is the African relapsing fever tick (Fig. 200), sharing in part the characters of the genus Ornithodorus, viz.: "Body flat when unfed, but usually becoming very convex on distention. Anterior end more or less pointed and hood-like. Margin thick and not clearly defined, similar in structure to the rest of the integument, and generally disappearing on distention. Capitulum subterminal, its anterior portions often visible dorsally in the adult. Disks present or absent; but when present not arranged radially (see Argas). Certain fairly constant grooves and folds on the venter, namely, a coxal fold internal to the coxæ, a supracoxal fold external to the coxæ, a transverse pre-anal and a transverse post-anal groove or furrow, and a post-anal median groove. Eyes present or absent."

O. moubata occurs only in Africa, is an eyeless species with a specific arrangement of the "humps" on the protarsus of the first pair of legs, being "subequal and tooth-like." The adults measure from 8 to 11 mm. in length and about 7 mm. in breadth. "The color varies from dusty brown to greenish brown in living specimens and turns reddish or blackish brown in alcohol." Eggs are deposited in small batches of from 10 to 80 at intervals of from three to fifteen days during a period of several months. The eggs are apparently readily deposited in captivity upon sand, as the writer has observed in other species of Ornithodorus. Hatching takes place in from ten to fifteen days and over, depending on temperature. Experimentally at least, the active larvæ attach themselves to a warm-blooded host, remaining attached for nearly a week, when they become disengaged and molt, the nymph now appearing. The nymphs feed at intervals, molting once or twice between each meal; there may be 6–9 molts and apparently young females molt even after sexual maturity has been reached, according to various observers, and individuals may remain infective for over a year. Wellman has observed that this species attacks a wide range of animals besides man, notably pigs, dogs, goats and sheep; Nuttall found them to feed in his laboratory on rabbits, mice, rats, monkeys and fowls.

FIG. 200. — African relapsing fever tick, *Ornithodorus moubata*. × 3.

African Relapsing Fever is a disease of man occurring in Africa (Congo Free State, Angola and elsewhere), is caused by *Spirochæta duttoni* Novy and Knapp and is therefore a *Spirochætosis*. The symptoms are described by Nuttall (1908, *loc. cit.*) viz.: "headache, (especially at the back of the head), vomiting, abdominal pain and purging, with severe fever, a pulse of 90–120, dry hot skin, congested eyes and shortness of breath. After a period of fever lasting about two days, there is a fall of temperature, but a fresh attack soon follows. These relapses occur more frequently than in European relapsing fever, being usually 5 to 6 in number, but there may be more. The attacks leave the patient in a weak condition for a long time after recovery, which usually follows, but death occurs in about 6 per cent of the cases."

Dutton and Todd in 1905 and R. Koch in the same year showed that *Ornithodorus moubata* is a common and probably the usual carrier of this spirochæte disease. Leishman as well as Nuttall has shown that the tick is infective only through its excreta and not by its bite, that the clear coxal secretion is an anticoagulant and non-infective. The infection is hereditary in the tick as in Texas cattle fever, and what is more the spirochæte is transmitted to at least the third generation of ticks. The attack of fever takes place in the human in from 5 to 10 days after the tick has bitten.

Control. — Wellman's [1] recommendations, in part, to the government of Angola for the control of African relapsing fever are as follows:

"(1) The tick in question should be regularly destroyed in crowded centers by disinfecting native houses, barracks and other permanent quarters, and by burning old camps, huts, etc.

"(2) Soldiers, laborers on plantations, etc., should be made to keep their houses clean and to sleep in hammocks, or on beds well raised from the floor and away from the wall. Natives should never be allowed to sleep in or near the quarters of Europeans.

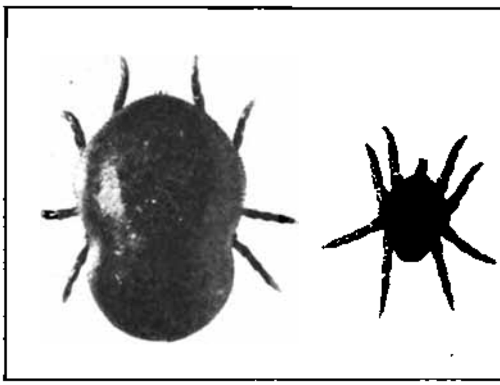

Fig. 201. — Spinose ear tick, *Ornithodorus megnini*. × 3.5.

"(3) Soldiers, porters, servants, plantation laborers and other controllable bodies of natives should be compelled to observe regulations regarding regular bathing and washing of clothes."

The Spinose Ear Tick, *Ornithodorus megnini* Duges (Fig. 201), occurs commonly in California and other subtropical parts of the United States and Mexico. It receives its name from the fact that the nymph is covered with numerous spines and in all stages the tick attacks the ears of cattle, horses, mules and occasionally other domesticated animals and man. Rather large dark eggs are deposited by this species on the ground, where the seed ticks hatch in two or three weeks (as short as eleven days according to Hooker).[2] Hooker furthermore states that the replete females creep upwards several feet before ovulation so that the larvæ upon emerging find themselves in an advantageous position

[1] Wellman, F. C., 1906. Human Trypanosomiasis and Spirochætosis in Portuguese South-west Africa with suggestions for preventing their spread in the colony. Journ. of Hygiene (Cambridge), Vol. VI, No. 3, pp. 237–245.

[2] Hooker, W. A., 1908. Life history, habits and methods of study of the Ixodoidea. Journ. of Econ. Ento., Vol. 1, No. 1, pp. 34–51.

to reach the head and enter the ears of the host. The writer's observations, however, indicate that the eggs are at least commonly deposited on the ground and that the larvæ crawl up weeds and other vegetation as do other seed ticks and reach the host's head while grazing. The larvæ feed in the deeper folds of the host's ears for from five to seven days, molting *in situ,* begin feeding again as nymphs, continuing their infestation for several weeks before leaving the ears. After the last molt, which occurs about seven days after leaving the host in midsummer or early autumn, they begin depositing eggs.

Damage Done. — The writer has received many complaints from various cattle grazing districts in California relative to the "ear tick." Ears are occasionally sent in thoroughly infested with these pests in all stages. It is commonly asserted that this tick is responsible for much deafness in domesticated animals, and it is also believed to be responsible for illness and even death, particularly in calves.

Treatment. — Owing to the position occupied by the ticks on the host only local treatment is of any avail. Good results are ordinarily secured by flooding the ear with carbolated olive oil or linseed oil, which causes the parasites to vacate, whereupon they may be easily removed and destroyed by crushing or placing in kerosene.

Other species of Ornithodorus. — *Ornithodorus savignyi* Audouin, occurs in Africa, is known as a venomous species and is believed to be a carrier of relapsing fever; *Ornithodorus coriaceus* C. L. Koch, known as the "Pajaroello," occurs in California and Mexico and is undoubtedly one of the most venomous species of ticks. (See Chapter XX.)

CHAPTER XIX

MITES

Class Arachnida, Order Acarina

Characteristics. — In the mites, as in the ticks, the abdomen is broadly joined to the cephalothorax with little or no evidence of separation. All species are very minute, most of them just about visible to the naked eye. The mites have four pairs of legs as have other Arachnids, but possess only three pairs (exceptionally less) as larvæ. The mouth parts are more or less tick-like and are fitted for piercing. One or more pairs of simple eyes are usually present. The respiratory system is in most species similar to that of the ticks, *i.e.* tracheal. Nearly all species deposit eggs; however, there are a few which are viviparous, among them Pediculoides. From the egg there emerges the hexapod larva, which molts shortly and then presents its fourth pair of legs. The life history of many species is passed in less than six weeks, in some as short as two weeks.

An infestation of mites is termed *acariasis*. Those species which burrow into the skin, producing channels and depositing therein their eggs, are said to produce *sarcoptic acariasis*, e.g. *Sarcoptes scabiei* var. *suis* of swine mange; while those species which deposit their eggs at the base of the hairs of the host or on the skin and pile up scabs, are said to produce *psoroptic acariasis*, e.g. *Psoroptes communis* var. *ovis* of sheep scab.

A. Mange, or Itch Mites — Sarcoptic Acariasis

Family Sarcoptidæ

Characters of Sarcoptidæ. — All members of the family Sarcoptidæ, commonly known as the itch mites, mange mites or scab mites, are very small (just about visible to the naked eye), whitish and somewhat hemispherical in form. Banks[1] characterizes this family, viz.: "The body is entire, and the surface transversely striated and provided with a few bristles, often short, stout and sharp-pointed. The legs are short and stout, arranged in two groups. The anterior legs are usually larger than the others. The tarsi commonly terminate in a stout claw. There

[1] Banks, Nathan, 1905. A treatise on the Acarina, or mites. Proc. U. S. National Museum, Smithsonian Institution, Washington, D.C., Vol. XXVIII, pp. 1–114.

is generally a long pedicellate sucker, sometimes with a jointed pedicel. The claw or sucker may be absent and in its place a long bristle. The legs often show a chitinous framework of rings, both transverse and oblique. On the front of the body is a prominent beak. The palpæ are small, three-jointed and appressed to the sides of the beak beneath. . . . There are frequently sexual differences; some males have the third pair of legs very large and long, while the fourth pair is very small. Sometimes there are plate-like lobes at the tip of the male abdomen, and the tarsi may terminate differently in the two sexes."

The family Sarcoptidæ includes a number of important genera, among them Sarcoptes, Psoroptes, Chorioptes, Otodectes and Cnemidocoptes.

Mange or Itch Mites. — The mange or itch mites belong to the genus Sarcoptes, have very short legs, the posterior pair not extending beyond the margin of the nearly circular body (Fig. 202); suckers are present on the first and second pair of legs. The sarcoptic mites burrow in the skin, where they produce definite burrows in which the females deposit their eggs.

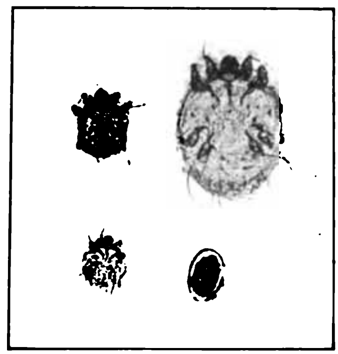

Fig. 202. — Showing life history and general characteristics of a typical sarcoptic (mange or itch) mite; egg (lower right); larva (lower left); male (upper left); female (upper right). *Sarcoptes scabiei* var. *suis*, the itch or mange mite of swine. × 57.

The species of Sarcoptes inhabiting the skin of mammals are ordinarily termed varieties of *Sarcoptes scabiei* L., the differences being very slight and many of them may interchange hosts, e.g. *Sarcoptes scabiei* var. *suis*, parasitic on swine and on man, and when on the latter is known as *S. scabiei* var. *hominis; Sarcoptes scabiei* var. *equi* of the horse is also parasitic on man. Given parasites, however, ordinarily exist only for a limited time on another host.

Human Itch. — The itch mite attacking humans is known as *Sarcoptes scabiei* var. *hominis*. It attacks by preference the thin skin between the fingers, the bend of the knee and elbow, the penis and other parts of the body, producing an almost intolerable itching. Infestation is ordinarily secured by direct contact, hand shaking, etc.

Life History of Itch Mite. — The female mites deposit their rather large oval eggs in the tortuous tunnels which they have made in the epidermis. From 10 to 25 eggs are deposited by each individual. "The female, having deposited her complement of eggs, dies at the end of her burrow. As the skin of the host is always wearing off, and constantly being renewed from below, the eggs, when ready to hatch, will be close to the surface, so that the mites may readily escape. Above each burrow there is often a little pimple, containing a watery fluid"

(Banks). The hexapod larvæ hatch in three or four days. In this stage the area of infection is most rapidly increased. Maturity is reached in ten to twelve days, during which time there are said to be three molts. Gerlach, according to Braun,[1] has found that the progeny reproduce again in fifteen days, and that each female produces about fifteen individuals, after which she dies. Hence the descendants of one pair of mites in three months would number 1,500,000, which accounts for the rapid spread of itch on the individual host.

Treatment of Human Itch. — Inasmuch as the mites are protected in their tunnels in the epidermis, the skin must be thoroughly softened with soap and hot water before a remedy is applied. Sulphur ointments give very good results if applied repeatedly at intervals of three or four days. Tar, creolin, balsam of Peru, tincture of iodine, etc., are also used. Underclothing coming in contact with the parts affected should be boiled. Cleanliness is essential to prevent infection.

Swine Mange. — Mange of swine is caused by *Sarcoptes scabiei* var. *suis* (Fig. 202), which resembles *Sarcoptes scabiei* var. *hominis* very closely, if it is not identical. Mange attacks the swine commonly about the top of the neck, shoulders, ears, withers and along the back to the root of the tail. A microscopical examination of deeper tissue from beneath scabs will usually reveal the mites. Comparatively few cases of swine mange have come to the writer's attention, even in localities where swine raising is carried on extensively, hence it seems that the disease is not as widespread as might be expected.

Suckling pigs and young shoats ordinarily suffer most. The affected animals scratch and rub vigorously, which may, however, be due to lice, but if the skin is cracked and thickly encrusted with heavy scabs, and the hair stands erect, an examination for scab mites should be made.

Infected animals should be isolated and immediately treated, the quarters should be disinfected with a 10 per cent creolin solution, 1 to 10 kerosene emulsion, 1 to 15 lime sulphur solution or the like.

The life history and habits of the swine mange mite correspond in every respect with the itch mite of humans.

Treatment for Swine Mange. — In the treatment of swine mange, it is necessary to apply external remedies, in addition to sanitary precautions to prevent spread and reinfection of treated animals. Remedies are best applied in the form of solutions for the reason that all parts of the animal's body are thus easily reached in the dipping process. Hand dressing or scrubbing or the application of ointments may be practiced where dipping is not practical, but even so all parts of the animal should be thoroughly treated.

Mayo[2] of the Virginia Polytechnic Institute recommends a "lime

[1] Braun, Max, 1908. The Animal Parasites of Man. (English Edition.) William Wood & Co. New York, xix + 453 pp.

[2] Mayo, N. S., 1910. Some diseases of swine. Bull. 189, Virginia Poly. Inst. Agr. Exp. Sta., 19 pp.

and sulphur" dip most highly. He uses 8 pounds of fresh lime and 24 pounds of flowers of sulphur to 100 gallons of water, slaking the lime with sufficient water to form a thick paste, sifting in the sulphur and mixing with a hoe. This mixture is placed in a kettle with 25 to 30 gallons of water and boiled for one hour at least, two hours being better. Mayo suggests using the entire mass for swine, which must not, however, be done for sheep. The dip is used warm at a temperature of from 100° to 110° F. This temperature may be maintained by running a steam pipe along the bottom of the dipping vat.

Prepared "lime and sulphur" dips can be secured readily on the market, and are commonly used at the rate of one part of the solution to fifteen parts of water, however, care should be exercised to use the dip as directed, owing to variation in constituents. Coal tar dips are also used extensively and give good results if used properly.

Dipping vats may be made of wood or concrete and are usually set in the ground at a slight elevation to insure drainage away from the vat. A convenient size for a vat is " ten feet long on top, eight feet long on the bottom, one foot wide on the bottom and two feet wide at the top. The end where the hogs enter should be perpendicular and the other end inclined, with cleats, so that the hogs can emerge after passing through. The entrance should be by a slide. For pigs and small shoats that can be easily handled, a barrel serves the purpose well; the pigs can be caught, plunged in the dip and held there the required time. Some successful swine raisers build cement bathing places or wallows for swine and keep these filled with a watery solution of some dip or disinfecting solution. If swine have wallowing holes filled with water, some of the good dips should be put in these frequently." The time to treat young pigs, and this is important, is at weaning time. Dipping twice as for older animals is necessary, and by placing them in uninfected quarters they ought to remain clean.

Mangy swine should be hand dressed with a stiff brush before dipping in order to loosen up scabs, and then kept in the dip long enough to permit the solution to soak through the scabs, certainly not less than two minutes. All the animals must be dipped a second time in eight or ten days in order to destroy the mites which have hatched from the eggs which are not destroyed.

Mayo (1910, *loc. cit.*) recommends a disinfecting whitewash to be applied to pens, etc., viz., " Fresh lime, 25 pounds, flowers of sulphur, 15 pounds, mix the sulphur with a little water, to a paste, add 30 gallons of water and cook for an hour, then add water sufficient to make 50 gallons and apply with a spray pump, using a 'Bordeaux' nozzle."

Equine Mange. — Sarcoptic acariasis in horses, mules and asses is caused by *Sarcoptes scabiei* var. *equi*. This species is also transmissible to man and is said to be the chief cause of the itch of cavalrymen and others handling horses extensively. Infestations on humans only last for two or three weeks.

The most reliable diagnostic character is the discovery of the mite, which is accomplished as in swine mange. The usual symptoms[1] are first of all a strong tendency to rub some circumscribed part such as the head, root of the mane or tail, withers or back, due to an incessant itching. If a person scratches the affected parts, the animal moves its lips as though it were nibbling. The skin of these parts also shows an eruption of "fine conical papillæ." The hair here stands erect and bristly, many having dropped out, but totally bare spots in which there are no isolated hairs apparently do not occur in mange, but do in ringworm according to Law. The affected parts are at first scurfy, then become covered with yellowish scabs, which latter exude matter due to the rubbing and inflammation, and finally there are formed scabs and crusts, often with deep crevices. During the first fourteen days the progress of the disease is usually slow, but by the sixth week the ravages of the disease become extensive and there is rapid progress.

The life history and habits of *Sarcoptes scabiei* var. *equi* correspond in every respect with other species already described.

Treatment of Equine Mange. — Before applying a local remedy for mange it is necessary to clip the entire animal so as to disclose all points of attack which might otherwise be hidden by hair. The clipped hair must not be blown by the wind and should be burned. The parts affected are next thoroughly lathered and left for a short while to soften, after which warm water is applied and the scabs rubbed off as far as possible with wisps of hay or straw and these also burned. The affected parts are now ready for a parasiticide, which must be applied by hand.

Many remedies may be had for mange, all of which have more or less virtue, but the writer has found that those containing sulphur have the greatest virtue. The ordinary "lime and sulphur" sheep dips applied locally and thoroughly, repeated three or four times at intervals of five days, ordinarily prove effective. Among other remedies Law (1905, *loc. cit.*) recommends creosote, 5 parts, alcohol, 5 parts, water, 25 parts; to be rubbed in thoroughly two or three times at intervals of from three to five days. The application of a 2 per cent solution of Chloronaphtholeum applied as above proves very satisfactory, as does Kreso dip, one to forty.

Stalls in which mangy horses have been kept must be disinfected with live steam or boiling water or mercuric chloride one part to 500 of water. If the latter is used its very poisonous properties must be considered. Brushes, scrapers, rubbers, etc. must be boiled; harness must be rubbed thoroughly with a strong disinfectant, for example 2 per cent formaldehyde, or Chloronaphtholeum.

Bovine Mange. — Sarcoptic acariasis, or mange, in cattle is said to be rare; however, the psoroptic form (scabies) is quite common.

[1] Law, James, 1909. Textbook of Veterinary Medicine. Vol. V., 621 pp. Ithaca, N.Y.

Canine Mange. — Mange of dogs is caused primarily by *Sarcoptes scabiei* var. *canis,* closely resembling the swine variety. Mange in the dog appears first on the muzzle, around the eyes, on ears and breast and later spreads to the back, abdomen and elsewhere. Symptoms are much as in swine and horses. Canine mange is evidently transmissible to humans.

Treatment for Canine Mange. — Long-haired dogs must be clipped before applying a remedy. Law recommends the following treatment: " the whole skin may be covered with a solution of equal parts of green

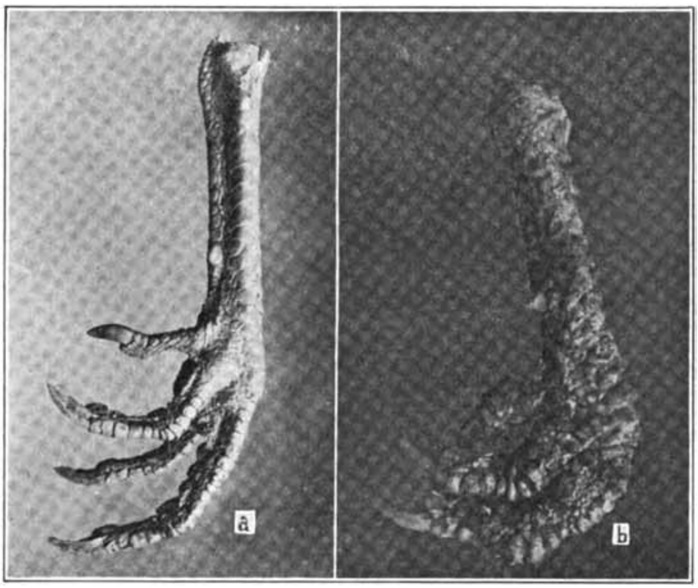

Fig. 203. — Showing (*a*) normal leg and claw of a fowl and (*b*) one affected with sarcoptic mites, *Cnemidocoptes mutans*, causing scaly leg.

potash soap and alcohol and just enough carbolic acid to give it the odor. This is washed off next day and the surface is covered with the following: Naphthalin, ½ oz., vaseline, 2 oz., or alcohol 1 pint makes a most agreeable, if somewhat expensive, dressing, which, though slow, is effective. Creolin, 1 part, in alcohol, 15 parts, is very efficient." Tobacco, carbolic acid and other poisons which may be licked off by the dog should not be used, unless a tight muzzle is provided.

Other Mange Mites. — Mange of cats is said to be caused by *Sarcoptes minor* var. *felis,* mange of goats by *Sarcoptes scabiei* var. *capræ,* and of camels by *Sarcoptes scabiei* var. *cameli.*

Scaly Leg Mite of Poultry. — The legs of domestic fowls (chickens, turkeys, pheasants, etc.) are frequently covered with heavy scales and incrustations (Fig. 203). This condition is produced by a burrowing mite (Fig. 204), *Cnemidocoptes* (*Sarcoptes*) *mutans* Robin. The mites burrow and live in the skin, depositing their eggs in these channels as do the mange mites. Scaly leg is easily transmitted from fowl to fowl, hence the infested birds should be isolated and treated.

Treatment of "Scaly Leg."—The legs must be soaked and manipulated with the hands in soap and warm water in order to soften the scabs. Then when dry, " apply a coating of balsam of Peru, or an ointment containing 2 per cent of carbolic acid " or " a mixture of one part of oil of caraway with five parts of vaseline " (U. S. Dept. of Agr., Farmers' Bull. 530). The writer has repeatedly recommended dipping the legs

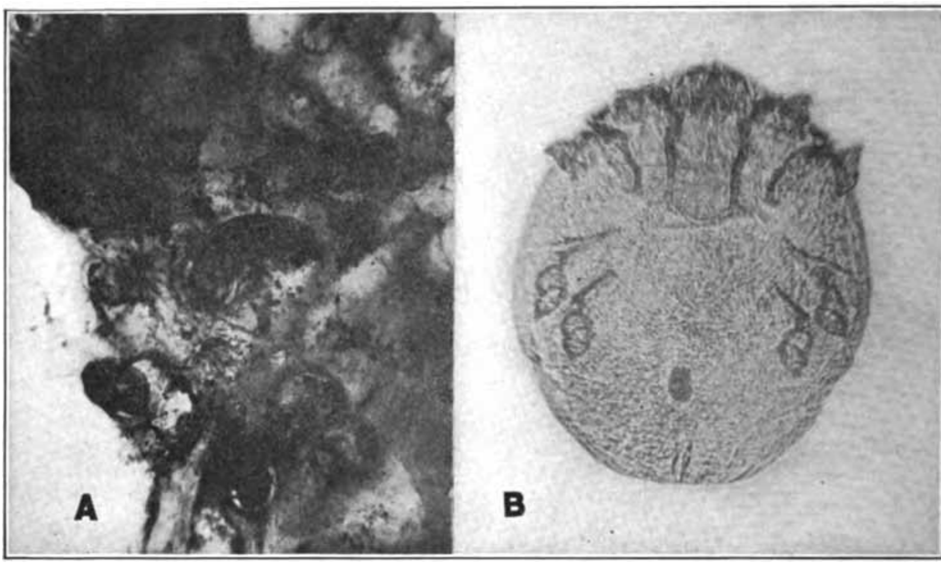

FIG. 204. — (*a*) Photograph of a portion of scale from a fowl affected with "scaly leg," showing mites (*Cnemidocoptes mutans*) *in situ;* (*b*) enlargement of an individual mite. × 170.

of the fowl in a vessel containing 1 part kerosene and 1 part linseed oil; the oil must not touch the feathers on the leg otherwise the skin may suffer. This dipping process is best done while the birds are roosting, lifting each bird from the roost, dipping and then replacing it. The process should be repeated in not over a week.

Depluming Mite. — *Cnemidocoptes gallinæ* Railliet, known as the *depluming mite,* is closely related to the "scaly leg mite," but attacks the skin of the fowl near the base of the feathers. The mites themselves do not cause the bird to lose its plumage, but the intense itching caused by the mites impels the host to pluck its feathers in an attempt to reduce the itching.

Dipping the birds in a 2 per cent solution of creolin, or in a 2 per cent solution of Zenoleum, or rubbing the skin with a sulphur ointment will, if the treatment is repeated, relieve the trouble considerably.

B. Scab Mites — Psoroptic Acariasis

Family Sarcoptidæ

Characteristics of Psoroptic Mites. — The psoroptic or scab mites belong to the family *Sarcoptidæ* as do the itch and mange mites, hence partake of the family characteristics. However, in the psoroptic mites the legs are long and slender, all four pairs extending beyond the margin of the body which is elongate (Fig. 205). The "pedicel of the suckers is jointed" and the "mandibles styliform, serrate near tip" and suited for piercing. The psoroptic mites do not burrow, as do the sarcoptic

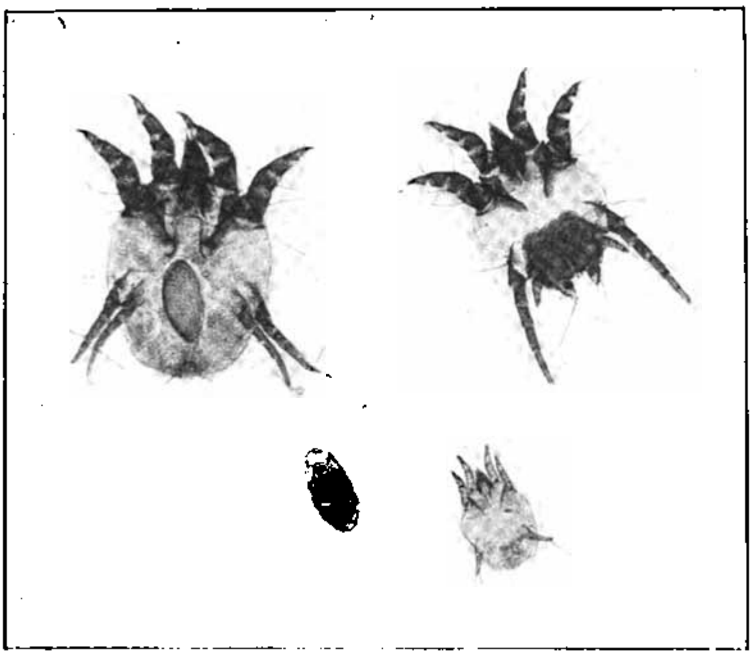

Fig. 205. — Showing life history and general characteristics of a typical psoroptic or scab mite. Egg (lower left); larva (lower right); male (upper right); female (upper left). *Psoroptes communis* var. *equi* of the horse. × 85.

mites, but live at the base of the hairs of the host, piercing the skin, causing an exudate which partially hardens, forming scabs which pile up as a crust of loose humid matter. This condition is known as *scabies* or *scab*. Among the piled up scabs are deposited the eggs. Owing to the loose condition of the scabs and the hardihood of the mites, this form of acariasis becomes quickly and easily distributed from animal to animal by contact and by rubbing against fences, trees, and the like.

The commonest scab mites belong to the genus Psoroptes of which *Psoroptes communis* var. *ovis* of the sheep is best known. Other varieties of this species infest cattle and horses mainly. Several species of psoroptic mites attack the ears of cats and dogs, *Otodectes cygnotis* Gedoelst.

Ovine Scabies (Sheep Scab) *Psoroptes communis* var. *ovis* (Fig. 206) is the causative organism of scabies in sheep. This is by far the

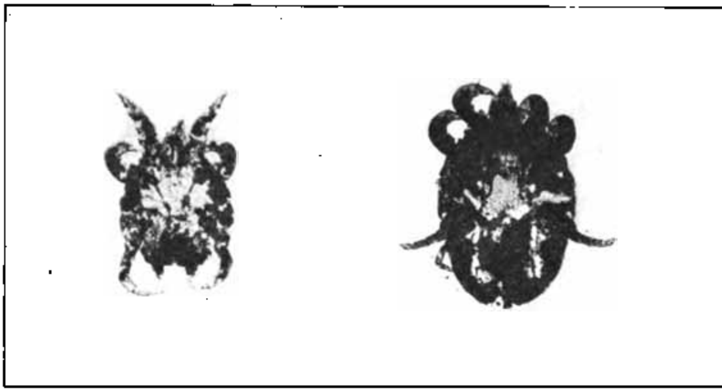

Fig. 206. — Sheep scab mite, *Psoroptes communis* var. *ovis;* male (left); female (right). × 75.

most important species of scab mite. However, with the widespread use of dips, and rigid quarantine regulations, scabies in sheep is gradually being controlled.

The sheep scab mite is easily visible to the naked eye. The adult female measures about "one fortieth" of an inch in length by "one-sixtieth" of an inch in breadth, and the male "one-fiftieth" by "one-eightieth" of an inch. As in all psoroptic species the mites are found on the surface of the body among the scabs at the base of the hairs. The parts of the body most thickly covered with wool are chiefly affected.

Fig. 207. — An advanced case of sheep scabies.

Symptoms of Sheep Scab. — Scabies is first indicated by a slight "tagging" of the wool, the coat becomes rough, ragged and matted at the points affected (Fig. 207). Tags of wool are torn away by the sheep or are left attached to rubbing posts and other objects against which the animal rubs. The sheep scratches vigorously and shows signs of intense itching. "The skin of the affected part is covered with yellowish papules of varying size, and a marked accumulation of scurf among the roots of the wool. Later the affected skin swells uniformly, and the increasing exudation concretes into a massive scab enveloping the roots of the wool, so that as it increases layer by layer on its deeper surface, it lifts the fibers out of their follicles, detaching the wool and leaving extensive bare scabby patches. The denuded surface shows all the variation of lesions shown in other mangy animals. Papules, vesicles, pustules, scabs, cracks, excoriations, and even sloughs may appear at different points. Sometimes in clipped sheep the exudate forms a uniform, smooth, parchment-like crust covering the whole exposed area. Around these bare patches the wool is encrusted at its roots, or shows a dark, dirty, scurfy layer composed of epidermic cells, yolk, dried exudate and the exuviæ of the acarus. Beneath this the parasite is found in myriads. The bare spots may show comparatively few" (Law).

Life History of the Scab Mite. — The female scab mite deposits an average of about 15 (maximum 30) eggs, one at a time, and the period of oviposition often lasts several days, when the female evidently dies. The eggs are either attached to the wool near the skin or deposited directly upon the latter. The hexapod larvæ hatch in from three to seven days, the first molt taking place in three or four days when the fourth pair of legs appears; a second and third molt takes place within the next four or five days. Sexual maturity is evidently reached about the time of the second molt. Although there is considerable variation in the length of time elapsing from egg to egg, twelve to fourteen days is ordinarily accepted as an average.

Treatment for Sheep Scab. — Internal remedies, such as sulphur, have been found to be unsuccessful by the U. S. Department of Agriculture. However, sulphur applied externally in the form of "lime and sulphur" dip has been used for many years as a successful remedy. Several kinds of dips with variations are commonly used against sheep scab, among them, lime and sulphur, tobacco and sulphur, tobacco, cresol, coal tar products, Chloronaphtholeum, Kreso, etc. If proprietary dips are used, extreme care must be exercised in following the directions. The dip should have the approval of the U. S. Department of Agriculture. All dips must be repeated in seven or eight days and not later than ten days in order to destroy the mites newly hatched from eggs, since very few dips, except perhaps creosote dips, are injurious to the eggs.

Lime and Sulphur Dips. — Experience in many sheep-raising districts has proved that lime and sulphur dips are most efficient in the control of scab, if properly used. Damage to the wool, if dipping is done shortly after shearing, is very slight indeed. If there is any doubt, or injury has been produced in the use of lime and sulphur, other dips are available, notably nicotine.

Among the varieties of lime and sulphur dips mentioned by the U. S. Bureau of Animal Industry [1] are the following:

[1] Salmon, D. E., and Stiles, Ch. Wardell, 1903. Scab in Sheep. U. S. Dept. Agr. Farmers' Bull. No. 159, 45 pp.

1. For fresh scab (U. S. B. A. I. formula):

Flowers of sulphur	24 lbs.
Unslaked lime	8 lbs.
Water	100 gals.

2. For very hard scab (Fort Collins formula):

Flowers of sulphur	33 lbs.
Unslaked lime	11 lbs.
Water	100 gals.

3. For unusually severe cases (Nevada formula):

Flowers of sulphur	16⅔ lbs.
Lime	33⅓ lbs.
Water	100 gals.

According to the U. S. Bureau of Animal Industry "thirty-three pounds of lime to one hundred gallons of water is the largest proportion admissible under any circumstance."

How to Prepare Lime and Sulphur Dip. — Much time may be saved by purchasing the lime and sulphur already prepared and using it as directed, but the mixture may be prepared as follows, as directed by the United States Department of Agriculture:

"*A*. Take 8 to 11 pounds of unslaked lime, place it in a mortar box or a kettle or pail of some kind, and add enough water to slake the lime and form a "lime paste" or "lime putty."

Many persons prefer to slake the lime to a powder, which is to be sifted and mixed with sifted sulphur. One pint of water will slake three pounds of lime, if the slaking is performed slowly and carefully. As a rule, however, it is necessary to use more water. This method takes more time and requires more work than the one given above, and does not give any better results. If the boiled solution is allowed to settle, the ooze will be equally as safe.

"*B*. Sift into this lime paste three times as many pounds of flowers of sulphur as used of lime, and stir the mixture well.

Be sure to weigh both the lime and the sulphur. Do not trust to measuring them in a bucket or to guessing at the weight.

"*C*. Place the sulphur lime paste in a kettle or boiler with about 25 or 30 gallons of boiling water, and boil the mixture for two hours at least, stirring the liquid and sediment. The boiling should be continued until the sulphur disappears, or almost disappears, from the surface; the solution is then of a chocolate or liver color. The longer the solution boils the more the sulphur is dissolved, and the less caustic the ooze becomes. Most writers advise boiling from thirty to forty minutes, but the Bureau obtains a much better ooze by boiling from two to three hours, adding water when necessary.

"*D*. Pour the mixture and sediment into a tub or barrel placed near the dipping vat and provided with a bunghole about four inches from the bottom and allow ample time (two to three hours, or more if necessary) to settle.

The use of some sort of settling tank provided with a bunghole is an absolute necessity, unless the boiler is so arranged that it may be used both for boiling and settling. An ordinary kerosene oil barrel will answer very well as a small settling tank. To insert a spigot about three to four inches from the bottom is an easy matter. Draining off the liquid through a spigot has the great advantage over dipping it out, in that less commotion occurs in the liquid, which therefore remains freer from sediment.

"*E.* When fully settled, draw off the clear liquid into the dipping vat and add enough warm water to make 100 gallons. The sediment in the barrel may then be mixed with water and used as a disinfectant, *but under no circumstances should it be used for dipping purposes.*"

The Dipping Vat. — Dipping vats may be constructed either of wood or of concrete, should be about nine inches wide at the bottom, two feet six inches at the top, about 5 feet deep, and thirty-five to forty feet in length. The entrance end is built steep while the exit end has a gradual slant provided with cleats.

How to Proceed. — The sheared sheep are driven into the receiving pan, the dip having been prepared in the meantime and warmed to 102° to 105° F. One after another the sheep are forced into the dip, in which they must be kept two minutes and the head drenched at least once while traveling toward the exit end of the vat (see Fig. 208). From the vat the sheep emerge in dripping pens.

Tobacco Dips. — Tobacco (nicotine) dips are now used very extensively with excellent results. Tobacco dips are used either with or without sulphur. Owing to variation in nicotine content, homemade dips or proprietary tobacco dips are not safe unless the percentage is ascertained. When diluted ready for use the *nicotine content must be .07 of one per cent,* — a requirement of the Bureau of Animal Industry.

After a very careful and rigid experiment conducted by the Kentucky Agricultural Experiment Station [1] in coöperation with the Bureau of Animal Industry with reference to the addition of sulphur, the following conclusions were reached:

"With the conditions under which this experiment was carried on, as given in this bulletin, the addition of flowers of sulphur in the prescribed dilutions of nicotine did not, as far as could be discerned, enhance the value of these dips in curing sheep of the disease of scabies.

After the conclusion of the above experiment, dippings were conducted by the Bureau of Animal Industry on the western ranges under field conditions. The results were confirmatory to the conclusions drawn from the above experiments and a ruling was made by the Bureau, taking effect May 1, 1911, withdrawing the requirement that sulphur be added to tobacco dips. The ruling requires that seven-hundredths of one per cent of nicotine be used at each dipping."

[1] Good, Edwin S., and Bryant, Thomson R., 1911. The dipping of sheep for scabies in tobacco dips with and without the addition of flowers of sulphur. Kentucky Agr. Exp. Sta. Bull. 157, pp. 183–193.

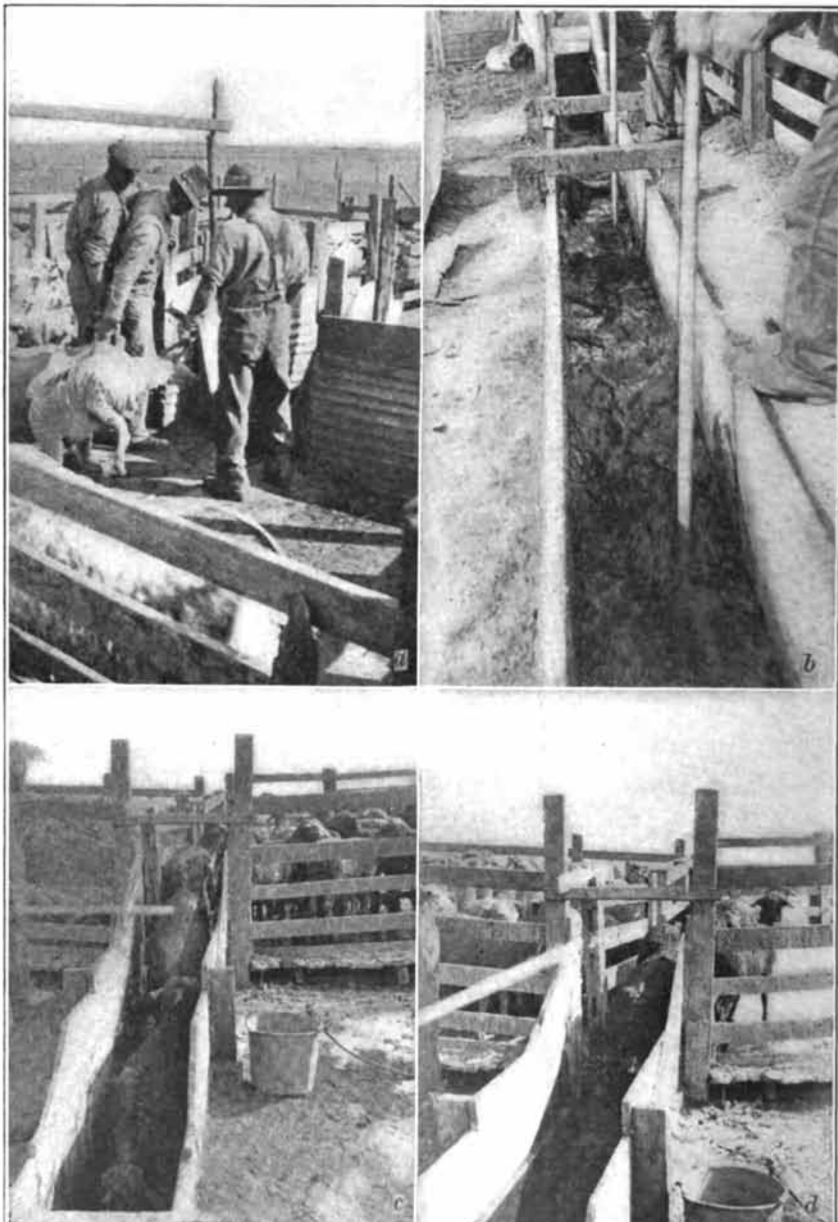

FIG. 208. — Dipping sheep. (*a*) plunging the sheep into the vat; (*b*) sheep swimming through the vat; (*c*) sheep emerging from the vat; (*d*) entering the pens after emerging from the vat. (Photo by G. P. Gray.)

The second dipping in the above experiment was given in ten days and the temperature of the water was 105° F.

A tobacco extract containing 2.9 per cent nicotine must (according to the above bulletin) be diluted with 56.85 gallons of water to produce .07 per cent nicotine dip, or 80.14 gallons of water for a .05 per cent nicotine dip. Nicotine sulphate (about 40 per cent nicotine) must be diluted with 86.17 gallons of water for .07 per cent nicotine or 120.70 gallons for a .05 per cent solution.

If sulphur is used with tobacco, 16 pounds of flowers of sulphur are required per 100 gallons of water. The sulphur is made into a thin paste with water before adding it to the dip.

Other Dips Used for Sheep Scab. — Great care should be exercised in selecting proprietary sheep dips; many are unreliable and result in waste of money, time and energy. The carbolic acid dips vary considerably in their cresol content even in packages sold under the same label. At all events use the dip exactly as recommended. Among the more widely used dips other than those mentioned above are Kreso, used 1 to 72, Zenoleum, 1 to 50, and Chloronaphtholeum, 1 to 50. The rating of the U. S. Bureau of Animal Industry should govern the choice of the remedy.

Bovine Scabies. — Scabies in cattle is caused by *Psoroptes communis* var. *bovis* and is comparatively common. The disease usually appears at the root of the tail, thighs, neck and withers and spreads rapidly to other parts of the body.

Treatment for scabies in cattle is most successfully undertaken with tobacco sulphur dips or lime and sulphur dips. The former is used as in sheep scab, while in the latter twelve pounds of unslaked lime and twenty-four pounds of flowers of sulphur to one hundred gallons of water are used.

The following general directions are given by the South Dakota Agricultural Experiment Station:[1]

"1. The temperature of the dipping vat should be constantly maintained at from 103° F. to 105° F.

"2. Animals badly affected are preferably to be hand dressed by scrubbing the scabby areas with a stronger solution of the dip. When lime and sulphur is used this has the effect of softening the firm scab, allowing the dip to penetrate.

"3. Each animal should be held in the vat for two minutes, and completely immersed twice.

"4. All animals that have been in contact with the diseased ones should be regarded as infected and dipped.

"5. The dipping should be repeated in from ten to fourteen days to destroy the parasites that may have hatched out subsequently to the first dipping.

[1] Moore, E. L., 1911. Scabies (Mange) in Cattle. Agr. Exp. Sta. South Dakota State College of Agr. and Mech. Arts, Bull. 131, pp. 203–216.

"6. Dipped cattle should not be returned to infected stables or corrals."

Equine Scabies. — Scabies of horses and mules is traceable to *Psoroptes communis* var. *equi* (Fig. 205). This variety is also known as the "long-nosed Psoroptes." Owing to the confluent sores, exudate, and smooth surface where scabs have been rubbed off this disease is also known as "humid mange." The mites are more easily discovered than in sarcoptic acariasis, and owing to the more exposed condition of the organisms the disease is easier of control.

Treatment of Equine Scabies does not differ materially from mange. Therefore the usual preliminary treatment with soap and water is pursued, followed with a parasiticide. Law strongly recommends Röll's formula of tar and sulphur ½ lb. each, green soap and alcohol, 1 pound each. The usual disinfection of stalls, harness, brushes, etc., must be pursued.

Fig. 209. — A follicle mite, *Demodex folliculorum*. × 110.

Mites in Ears of Rabbits, Cats and Other Animals. — A comparatively common affection of domesticated rabbits, also of cats and dogs, is known as *otacariasis* or parasitic *otitis* and is traceable to *Symbiotes auricularum* Railliet or *Otodectes cygnotis* Gedoelst, resembling Psoroptes very closely. The mites literally swarm in the ears of their host, causing much discomfort, tenderness of the ears, auricular catarrh, loss of appetite, wasting, torticollis, etc.

Cleansing the ears first with soapsuds and warm water, and then applying a sulphur ointment or a 10 per cent solution of tincture of iodine in glycerine, or a 1 per cent solution of carbolic acid in linseed oil is recommended. The hutches or kennels must be thoroughly disinfected with a strong lime and sulphur solution or carbolic acid to prevent further contagion.

C. Follicle Mites — Follicular Mange

Family Demodecidæ

Characteristics of Follicle Mites. — The Demodecidæ include very minute (.3–.4 mm.) mites with elongated transversely striated abdomen and possessing four pairs of "stubby" three-jointed legs (Fig. 209).

The follicle mite (*Demodex folliculorum* Simon) inhabits the hair follicles and sebaceous glands of men and other mammals "causing inflammation of the gland (comedones); their agglomeration in the meibomian glands (in man) sets up inflammation of the margins of the eyelids" (Braun). While the follicle mites may, under certain conditions, produce acne-like conditions, it is hardly probable that many cases of " blackhead " if any, may be traceable to these mites. They are nevertheless very common, — said to occur in 50 per cent of mankind in all parts of the world.

The variety found in man is known as *Demodex folliculorum* var. *hominis;* that of the dog as *Demodex folliculorum* var. *canis;* of the sheep var. *ovis;* of the ox, var. *bovis;* of swine, var. *suis*, etc.

In most animals the follicle mites are found in the region of the muzzle and the affection is known as *follicular mange*, manifested by a reddish raw appearance. According to Banks (1905, *loc. cit.*) *Demodex bovis* Stiles has been recorded from hides of American cattle in which swellings about the size of a pea were formed on the skin. In these swellings great numbers of the mites occurred. The value of the hides is said to be lessened to a considerable degree.

Owing to the fact that the follicle mites occur so deeply in the skin, treatment is made very difficult. Penetrating materials are necessary, for example, benzine, 1 part, and olive oil, 4 parts, or applications of tincture of iodine. Frequent applications must be made until a cure has been effected.

D. Harvest Mites or Chiggers

Family Trombidiidæ

Characteristics. — Members of the family Trombidiidæ are commonly known as "harvest mites," "jiggers," or "red bugs." In Mexico they are known as "Tlalsahuate." According to Banks they "are recognized by the body being divided into two portions, the anterior (cephalothorax) bearing the two anterior pairs of legs, the palpi, mouth parts and eyes; the posterior (abdomen) is much larger and bears the two posterior pairs of legs. The mandibles are chelate, at least there is a distinct jaw or curved spine-like process. They are always red in color, some, however, being much darker than others. The body is covered with bristles or feathered hairs according to the species. The palpi are five-jointed, quite prominent, often swollen in the middle, the penultimate joint ending in one or two claws, the last joint (often clavate) appearing as an appendage or " thumb " to the preceding joint. The legs are seven-jointed; the tarsi terminate in two small claws. The legs are clothed in the same manner as the body. There are two eyes upon each side of the cephalothorax, quite frequently borne on a distinct pedicel."

The most important genus affecting man is Trombidium, of which the larval form is known as Leptus (Fig. 210), *e.g. Leptus autumnalis* Shaw. Among the species of Trombidium are *T. holosericeum* Say, *T. magnificum*, Lec., etc.

Habits and Life History. — In the free-living adult stage the Trombidiidæ feed on insects and do not attack warm-blooded animals; the newly emerged larvæ at once become parasitic on grasshoppers and other insects, where they become full grown, molt and mature. In this stage (the larval) the mites also attack humans and other warm-blooded animals, but perish in the act of burrowing into the skin. Owing to the fact that the mites are so abundant during the autumn they are commonly called "harvest mites." Their chief habitat is among the weeds and tall grass in neglected pastures, among blackberry bushes and the like. The individuals which succeed in reaching maturity overwinter and deposit large numbers of eggs on the ground in sheltered weedy spots; these hatch in summer and autumn. There seems to be but one generation a year.

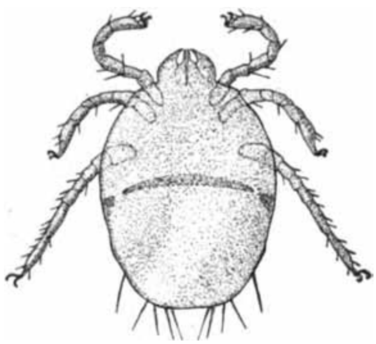

Fig. 210. — Chigger mite or harvest mite; — larva (Leptus) of Trombidium. × 150.

During midsummer and autumn it is almost impossible to traverse a mite-infested pasture without suffering an attack of intense itching about the ankles and up to the knees within a few hours. The mites are believed to enter the skin either through the pores, hair follicles, or even directly. There are formed red blotches often of considerable size and the itching is just about unbearable. Water blisters of larger or smaller size (1 to 5 mm. and over) appear in a day or two after itching begins.

Treatment for Harvest Mites. — The extreme irritation occasioned by these mites may be relieved considerably by bathing, using soap freely, followed by sponging with a weak solution of carbolic acid (an ounce to a quart of water), weak ammonia, soda solution, or alcohol, or anointing the affected spots with an ointment or salve containing sulphur. Rubbing the skin with tobacco water, benzine, kerosene, or glycerine is also suggested as a remedy, also as a preventative to persons finding it necessary to work in regions when the jiggers or red bugs are in season. Clearing infested spots of weeds, shrubbery, and tall grass is necessary to control the mites.

E. The Poultry Mite

Family Gamasidæ

Gamasid Mites. — The family Gamasidæ includes a large number of species parasitic mainly on birds and insects. The group is sometimes elevated to the rank of a superfamily (Gamasoidea) and then includes three families, viz., Dermanyssidæ, Gamasidæ and Uropodidæ. The close structural relationship of at least the first two hardly justifies this separation.

From our viewpoint the most important member of the family Gamasidæ (or Dermanyssidæ) is the poultry mite, *Dermanyssus gallinæ* Redi (Fig. 211).

Damage Done. — The poultry mite is one of the worst enemies of the poultry raiser in the Southern states and in California, and is evidently a serious pest in many other parts of the world. The damage which this mite produces is very considerable and may be summarized as follows: egg production is greatly reduced or entirely prevented as shown by Repp[1]; sitting hens are often caused to leave their nests or perish; newly hatched chicks perish in great numbers in the presence of these mites; chickens lose flesh, are unthrifty, and are unprofitable for marketing; loss of blood and reduced vitality produce birds easily susceptible to disease.

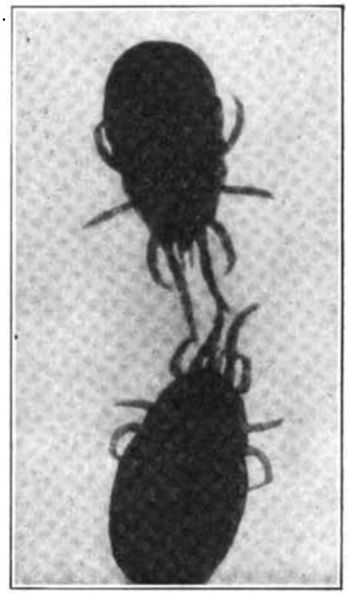

Fig. 211. — The poultry mite, *Dermanyssus gallinæ*. × 45.

Habits and Life History. — In size the mites vary from .6 to .7 mm. in length, are somewhat pear-shaped and are light gray when unengorged and from light to a dark red when engorged.

During the daytime the mites remain hidden in the crevices of the henhouse, under the roosts, under boards, etc. In these hiding places the eggs are deposited. At night the little pests swarm out from their hiding places and attack the fowls upon the roosts. Their attack on the fowls is, however, not restricted altogether to the night, but swarms of them may be found on sitting hens and laying hens during the day while nesting in darker situations.

Myriads of tiny eggs are deposited in all sorts of crevices. The six-legged larvæ hatch in four to six days, feed largely on filth at first and later attack the chickens, as do the adults. Full growth is reached in from three to six weeks, depending on temperature. Some authors give the time for development at from ten days to two weeks. There are three or four molts before sexual maturity is reached.

Control of the Poultry Mite. — Above all things extreme cleanliness and plenty of sunlight are necessary to prevent rapid multiplication. Kerosene emulsion (one part to ten parts of water) applied with a spray pump to all parts of the henhouse, particularly the crevices, has been found most serviceable in destroying the mites. The spray must be repeated in about five or six days to kill the mites hatching from the eggs, which latter are not injured by the spray.

[1] Repp. John J., 1903. The chicken mite. Iowa State College Exp. Sta. Bull. 69, pp. 287–294.

It is well to remove all roosts and paint these with kerosene or gasoline, daubing the ends abundantly with tar or crude oil before replacing.

Straight kerosene applied with a spray pump as directed for the chicken tick proves very effective, if repeated two or three times at intervals of five or six days.

F. Louse-like Mites

Family Tarsonemidæ

Characteristics of Tarsonemidæ. — This is a small family of soft-bodied mites having in the female a characteristic " prominent clavate organ of uncertain use " between the first and second pairs of legs (Fig. 212). The third and fourth pairs of legs are separated from the first and second pairs by a long interspace. There is present a considerable sexual dimorphism in the several species. The piercing, sucking mouth parts are provided with slender needle-like stylets. Many of the species are predaceous or parasitic, while others suck the juices of certain plants.

Fig. 212. — A louse-like mite, *Pediculoides ventricosus*. × 32.

Pediculoides ventricosus Newport is a widely distributed predaceous mite which attacks the larvæ of a number of species of insects such as the Angoumois grain moth (*Sitotroga cerealella* Oliv.), the wheat joint-worm (*Isosoma tritici* Fitch), the peach twig borer (*Anarsia lineatella* Zell.), the cotton-boll weevil (*Anthonomus grandis* Boh.), etc. It is therefore normally a beneficial mite, but unfortunately it also attacks man, producing a very disagreeable dermatitis.

While the male mite is very tiny, just about visible to the naked eye, the female when pregnant becomes enormously swollen, measuring nearly a millimeter in length, the abdomen presenting a globular appearance, the cephalothorax and appendages barely visible.

Within the enlarged abdomen of the female may be found rather large eggs which hatch internally, and the young mites develop to maturity within the body of the mother before being extruded. The number of young produced by the female is said to range from a few to nearly 300.

A number of epidemics of dermatitis have been traced to these mites, infection having been brought about by sleeping on straw mattresses or while laboring in grain fields at harvest time. The infection has been confounded with hives, scabies and even chicken pox and smallpox, and appears on the neck, chest, abdomen, back, arms, and legs, in fact the whole body may be involved and the itching is very intense. The eruption is commonly accompanied with fever as high as 102° F.

According to Goldberger and Schamberg [1] the itching subsides under continuous exposure in from 3 to 7 weeks. They also recommend treating the affection with an ointment of beta naphthol, sulphur, benzoate and lard.

To destroy mites in the straw of mattresses or in other situations, fumigation with sulphur or formaldehyde gas or steaming is recommended.

As to prevention Webster [2] suggests burning the grain stubble during the fall, winter or spring, also that threshing direct from the shock resulted in the control of the grain moth and consequently of the parasitic mites.

G. Flour and Meal Mites — Grocer's Itch

Family Tyrogliphidæ

Characteristics of Tyrogliphidæ. — This family includes a small group of very tiny mites, ordinarily about 0.5 mm. or less in length. Several of the species attack grain, flour, meal, dried meat, hams, dried fruits, insect collections, etc. Their development is so rapid that there may be literally millions of them in some stored products in a few days.

The metamorphosis of this group involves a peculiar stage known as the *Hypopus*, appearing after the larval and nymphal stages, very unlike either of these and very different from the adult. This stage is said to attach itself, non-parasitically, to flies and other insects, which serve as disseminators of the mites.

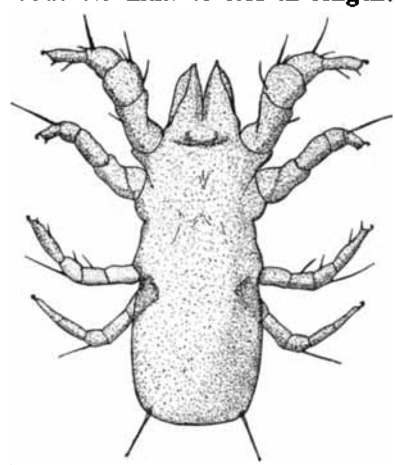

Fig. 213. — A stored food mite or flour mite, *Aleurobius* (*Tyroglyphus*) *farinæ* (male). × 145.

Persons handling stored products, cereals, flour, meal, etc. may be attacked temporarily by the mites, causing severe itching and irritation of the skin, known as "grocer's itch."

Tyroglyphus siro Linn. is the cheese mite, also found in grain and stored products; *T. farinæ* De G. (Fig. 213) is known as the flour mite but is probably the same as the former.

[1] Goldberger, J., and Schamberg, J. F., 1909. Epidemic of an articariod dermatitis due to a small mite (*Pediculoides ventricosus*) in the straw of mattresses. U. S. Public Health Reports, Vol. 24, No. 28, pp. 973–975.

[2] Webster, F. M., 1910. A predaceous mite proves noxious to man. U. S. Dept of Agr. Bu. of Ento. Circ. No. 118, 24 pp.

No doubt the best way to destroy mites occurring in stored products is to subject them to a dry heat of 125° F., or by fumigation with sulphur or carbon dioxide.

H. Red Spiders

Family Tetranychidæ

Characteristics of Tetranychidæ.—To this family belong the "web-spinning mites," most commonly infesting vegetation and destructive to fruit trees and other plants. The term "red spiders" is ordinarily applied to the group. *Tetranychus bimaculatus* Harvey attacks many species of plants and is very injurious to hops.

Persons employed in picking hops and harvesting almonds, etc., often complain of itching produced by the red spiders, but this soon disappears.

CHAPTER XX

VENOMOUS INSECTS AND ARACHNIDS

Insect Venoms. — Insect venoms, like other animal venoms, are toxic principles probably not greatly unlike the bacterial toxins, but about which we know comparatively little. Unlike the bacterial toxins which reach injurious amounts after a period of incubation subsequent to the introduction of the corresponding bacteria into the body, the venoms on the contrary act almost instantly, *i.e.* as soon as introduced.

The venoms act in one or more ways when introduced into the body, 1st, they may act directly as solvents on the blood corpuscles (*hæmolytic*); 2d, they may act directly on the nervous system producing a shock or inhibiting reflexes (*neurotoxic*); 3d, producing an infiltration and congestion of blood (*hæmorrhagic*) often in the vicinity of the wound or deeper tissue, such as the mesenteries, etc. A given specific venom may produce one or more of the above conditions.

As has been discovered by various investigators and as is a matter of common observation, repeated inoculation of minute or attenuated quantities of a venom may lead to immunity, so also with venoms or poisons of bees, bedbugs, mosquitoes, fleas, cone-noses, etc.

In the ants, bees and wasps (aculeate hymenoptera) there are two poison-secreting glands, one of which produces *formic acid* and the other an *alkaline* fluid. The combination of the two agents in certain proportions is evidently necessary to produce the reaction of a bee sting.

The scorpion (an Arachnid) secretes a large quantity of colorless acid-reacting liquid soluble in water and heavier than the same. According to Calmette, less than 0.0005 gm. will kill a white mouse in about two hours.

How the Venom is Introduced. — Venoms of insects in a broad sense are introduced into the bodies of animals in one of three ways: 1st, by *contact*, *e.g.* irritating hairs of certain caterpillars, such as the brown-tail moth (*Euproctis chrysorrhœa* Linn.), producing a condition similar to nettling, or the vesicating fluids of the blister beetles (Meloidæ), particularly *Lytta vesicatoria* Linn.; 2d, by the *bite* or thrust of a piercing proboscis, as in the cone-noses (Reduviidæ), or pierce of the chelicerae of spiders; 3d, by the *sting*, as in the bees or wasps (aculeate Hymenoptera) and the scorpion. The operation and structure of stings varies considerably, notably in the examples cited.

Irritating or Nettling Hairs. — A rash known as the "brown-tail rash" is traceable to the caterpillar of the brown-tail moth (*Euproctis* *chrysorrhœa* Linn.), a common and very destructive shade tree pest in Europe and in America, especially New England. When the caterpillars of this species molt, myriads of tiny barbed hairs are shed with the skin. When dry these hairs are blown about by the wind and coming in contact with the skin of the face or hands produce a very severe dermatitis. The hairs are hollow and it has been shown by Tyzzer that they contain a definite poisonous principle which is injected into the circulation by the sharp-pointed hair in contact with the skin, thus producing the rash.

Blister Beetles. — Blister beetles belong to the family Meloidæ (= Cantharidæ) (Order Coleoptera) and are so designated because of their vesicating properties, *i.e.* the application of the pulverized bodies of many species, if not all, produces a blistering of the skin. The most notable example of the Meloidæ is the Spanish fly, *Lytta vesicatoria* Linn. (see Chap. VI).

The Meloidæ (= Cantharidæ) are described by Comstock, viz., " The blister beetles are of medium or large size. The body is comparatively soft; the head is broad, vertical and abruptly narrowed into a neck; the prothorax is narrower than the wing covers, which are soft and flexible; the legs are long and slender; the hind tarsi are four-jointed, and the fore and middle tarsi are five-jointed."

The blister beetles deposit their eggs on the ground, the larvæ are active and feed it is said in some species on the eggs of locusts and solitary bees, others are predaceous. They undergo a number of changes not usual to insects and their development is consequently termed hypermetamorphosis. The adults are vegetable-feeding.

Venomous Insects

Cone-noses or Kissing Bugs, belonging to the Fam. Reduviidæ (see Chap. VIII), are most commonly concerned with the more painful "bites" inflicted by insects. Their mouth parts (see Chap. IV) are beautifully adapted to piercing the skin or covering of the host. The Reduviids are essentially predaceous, attacking many species of insects, particularly plant lice and other soft-bodied forms from which they suck the body fluids. Attack upon humans is made principally, if not wholly, in self-defense. Persons picking up boards, sticks or stones, etc., may accidentally also pick up one of these insects, or in plucking a leaf or flower from a tree or other plant the fingers may close upon the insect as well, with the result that a very painful bite is almost invariably inflicted.

The principal offenders are about 18–20 mm. in length and all bear a general resemblance to the illustration (Fig. 214). Among the important species in their relation to human comfort are the following: *Opsicoetes* (*Reduvius*) *personatus* Linn., known as the "kissing bug"; *Conorhinus sanguisuga* Lec., the "blood-sucking cone-nose" or "big bedbug"; *Conorhinus protractus* Uhler, the "China bedbug"; and *Rasahus biguttatus* Say, the "two-spotted corsair."

The symptoms produced by *Conorhinus protractus*, the usual culprit in California, are described as follows: "In a few minutes after a bite the patient develops nausea, flushed face, palpitation of the heart, rapid breathing, rapid pulse, followed by profuse urticaria all over the body. The symptoms vary with individuals in their intensity."

FIG. 214. — A typical blood-sucking cone-nose, *Conorhinus protractus*. × 2.

The symptoms described for *Rasahus biguttatus* are as follows: "Next day the injured part shows a local cellulitis with a central spot; around this spot there frequently appears a bulbous vesicle about the size of a ten-cent piece and filled with a dark grumous fluid; a smaller ulcer forms underneath the vesicle, the necrotic area being generally limited to the central part, while the surrounding tissues are more or less swollen and somewhat painful."

Treatment for Cone-nose Bites is discussed in a previous chapter (Chap. VIII).

Bedbugs (Fam. Acanthiidæ = Cimicidæ), **Fleas** (order Siphonaptera) and **Mosquitoes** (Fam. Culicidæ), all inflict bites of greater or less severity, depending on individual cases. To many persons the bite of any one of the above proves benign, while to others even one bite may prove very irritating. Frequently the severity of a bite is traceable to an infection induced by undue scratching with the finger nails. Ordinarily the itching may be relieved by the application of ammonia. For a discussion of each of the groups the reader is referred to the respective chapters dealing with the same.

THE BEE STING — STRUCTURE AND OPERATION

The Bee Sting. — For precision exhibited in minute parts and for accuracy of operation, the sting of the honeybee (*Apis mellifera* Linn.) stands unsurpassed among the weapons of defense and offense carried by insects. From the barefoot boy that plays in the flower-dotted meadow, to the philosopher delving in the mysteries of a locust blossom at close hand, the sting of the bee demands instant respect. Cheshire has nicely stated the matter thus: "Man and bees alike live in a world where good and evil grow together, where the thrift of the industrious excite the cupidity of the idle. Let us then, accepting the sting without regret, strive to learn the way in which, for us, it shall cease to be an evil."

The following account of the morphology and operation of the bee sting has been prepared by Miss Edwina Fay Frisbie and is an extract from a thesis on this subject prepared under the direction of the writer.

Morphology of Sting. — Accepting the sting as a specialized ovipositor the worker bee, or aborted female, is used. The sting can be easily extracted either by separating the segments of the abdomen from it by means of dissecting needles, or by squeezing the live bee between forceps, which pressure causes it to protrude the sting. The sting can then be grasped with other forceps and drawn out. After extraction, the sting can be best examined when the parts are floated out in a few drops of glycerine. For purposes of description the sting may be divided into three parts, viz.: the piercing apparatus; the lateral plate and appendages; the poison sac and glands.

FIG. 215. — Sting of a honeybee (*Apis mellifera*). *a*, the two serrated darts; *b*, *b'*, sting palpi; *c*, venom (poison) sac; *d*, venom gland; *e*, *e'*, triangular plates or levers; *f*, *f'*, semilunar plates or levers; *g*, *g'*, lateral plates or levers; *h*, *h'*, *y*-shaped darts; *i*, *i'*, points of attachment for darts to levers; *e*, *e'*; *j*, *j'*, points around which levers rotate; *k*, *k'*, points of attachment for levers *f*, *f'*. × 17.5.

The piercing apparatus itself consists of three parts, one the so-called sheath, the other two lying within the sheath, and partially surrounded by it. In appearance the sheath is yellowish and translucent. The darts, which present concave surfaces to one another, are highly chitinous. The distal one third of the dart possesses a series of sharp barbs, whose shape has been aptly compared to the tip of a crochet needle. Cheshire states that each dart has from three to six barbs, other writers seem doubtful as to the number. The careful observations of the writer in which many barbs have been examined give no instance in which it was impossible to distinguish *ten* barbs on the outer edge of each dart (Fig. 215). Several writers state that poison pores are to be found at the base of each barb, from which poison exudes. In this matter, experience forces the writer to agree with Snodgrass in his remark that thus far he has failed to observe the exit of poison elsewhere than between the darts at their tip.

Proceeding upward on the dart from the tiny barbs, the darts are seen to form a figure Y as they lie within the sheath. The arms of the Y gradually bend laterally. The plates attached to the upper edges of these laterally bent arms will be described under the next heading. One of the most remarkable portions of the darts is the poison valve with which each is provided. At the point of separation, the darts each present a delicate cup-shaped valve, whose closed portion is directed downward toward the tip of the sting. This is formed of the same chitinous material which composes the darts, and each is free to move with the movement of the dart. In order to accommodate this enlargement of the darts, the sheath at this point expands to about five times its smallest diameter, which is at the tip of the sting. For at least one third of its length the sheath at this portion is expanded into a symmetrical oblong body providing ample room for the movement of the darts and valves within.

A curious structure, said by many writers to be found on the sheath, consists of two delicate, but strong, chitinous tracks or guide rails on which the darts, correspondingly grooved, fit and move back and forth. Since the sheath does not sufficiently surround the darts to direct their course, this guide-rail system which Carlet has observed, and which is accepted by other authors, offers a pretty and probable solution of the reason for the smooth and accurate play of the darts within the sheath.

Lateral Appendages. — The lateral appendages are of three kinds, viz.: semilunar, triangular and lateral, according to shape or position. Both the semilunar and triangular plates are attached to the bent ends of the Y-shaped darts. The triangular plates are attached to the arms of the darts almost at their extremities, while the semilunar ones are connected for about one third of the distance from the ends of the arms. Permitting this comparison of the smallest of the plates to a triangle, although the comparison is not an exact one, the explanation of its position may be continued by saying that the apex of the triangle is that portion which is attached to the extremity of the dart. The other two points then point outward and downward, and serve as points of attachment for two elevated edges on the lateral plates which hang thus suspended. As they hang, half of their surface lies above and covers the dorsal surface of the semilunar plates just beneath them. Continuing in the same straight line with the semilunar plates and attached at their extremity to them, lie the fleshy palpi covered with delicate hairs. This outline description of the position and attachment of movable plates will be supplemented in the explanation of their mechanism, where they can be more readily understood through their function.

Venom Sac and Glands. — The third portion which completes the structure of the sting is the venom sac and glands. In order to understand these, it is necessary to know that Hymenoptera are divided into those which kill their prey by stinging, and those which only paralyze them. The former are the most complicated for they possess two poison glands. One, the formic acid gland, which opens directly into the great poison sac, is the larger of the two. The other, the alkaline gland, which is comparatively small, is situated at the base of the poison sac. It is the combination of the formic acid and alkaline substances from the two glands that results in the death of the attacked insect, or that causes the extreme irritation in humans.

The formic acid gland alone is found in the Hymenoptera, which only paralyze their prey when stinging them. This fact has led various observers to make chemical tests of both the formic acid and alkaline substance. The result, according to Carlet and others has been to show that neither substance by itself is effective except to paralyze, but when combined the substances have deadly effects upon other insects. Carlet's experiments to prove this were made upon house flies and blow flies by injecting each substance singly and then introducing both into the body of a fly. The results are entirely convincing.

Operation of the Sting. — After considering the very complicated structure of this minute instrument of attack and defense it will not be surprising to find, perhaps, that the mechanism of its parts is even more complicated and at the same time so wonderfully accurate that human invention can only look and marvel.

The microscopic structure of parts makes an examination of the mechanism extremely difficult. Also the stubbornness which characterizes a bee when it would be persuaded to sting without the usual incentive, adds to the problem of studying the operation of the sting. An effort was made to see the sting in operation by confining a bee on its dorsal side and then prodding it until its sting was angrily thrust in and out. This process showed three things, viz.: that the sharp-pointed sheath was always first to appear when the thrust was made; second, that the darts inside the sheath worked back and forth alternately, and quite independently of the sheath or of one another; third, that the poison was exuded in droplets from the tip of the sting between the darts. Beyond these points, observation of the mechanism of the sting was impossible, but the description of Cheshire's observations gives a very clear and plausible explanation.

"The sheath has three uses; first, to open the wound; second, to act as an intermediate conduit for the poison; and third, to hold in accurate position the long-barbed darts. The sheath does not inclose the darts as a scabbard, but is cleft down the side which is below, when the sting points backward. The darts, as soon as their ugly barbs establish a hold, first one and then another drive back and forth by successive blows. These in turn are followed by the sheath, when the darts again plunge more deeply, until the murderous little tool is buried to the hilt. But these movements are the result of a muscular apparatus yet to be examined. The dovetail guide-rails of the sheath are continued far above its bulbous portion, and along with these the darts are also prolonged upward, still held to the guides by the grooved arrangement; but both guides and darts, in the upper part of their length, curve from each other like the arms of the Y, before mentioned, to points *C*, *C′* (Fig. 215) where the darts make attachment to two levers (*i*, *i′*). The levers, or plates, as they are called (*Kl* and *K′l″*), are provided with broad muscles, which terminate by attachment to the lower segments of the abdomen. These, by contraction, revolve the levers aforesaid round the points *f*, *f′*, so that without relative movement of rod and groove, the points *c*, *c′* approach each other. The arms of the Y straighten and shorten, so that the sheath and darts are driven from their hiding place together and the thrust is made by which the sheath produces its incision and fixture. The sides being symmetrical, we may, for simplicity's sake, concentrate our attention on one, say the left in the figure. A muscular contraction of a broad strap joining *K* and *D* (the dart protractor) now revolves *k* on *l*, so that *a* is raised, by which clearly *c* is made to approach *d*; that is, the dart is sent forward, so that the barbs extend beyond the sheath and deepen the puncture. The other dart, and then the sheath, follow, in a sequence already explained, and which *G* is intended to make intelligible, representing the entrance of the sheath, *b* the advance of the barbs, and *c* the sheath in its second position. The barb retractor muscle is attached to the outer side of *i*, and by it *a* is depressed and the barbs lifted. These movements, following one another with remarkable rapidity, are entirely reflex, and may be continued long after the sting has been torn, as is usual, from the insect. By taking a bee under the microscope and forcing the sting into action, the sting movement will be seen to be kept up by continued impulses from the fifth abdominal ganglion and its multitudinous nerves, which penetrate every part of the sting mechanism and may be traced even into the darts. These facts will show why an abdomen separated many hours may be able to sting severely, as I have more than once experienced."

Sting in Situ. — It can readily be seen that the sting originates from the seventh and eighth segments and lies between the oviduct and the rectum above. The darts of the sting follow the ventral line of the abdomen and are held in place by the sheath situated just above, while the barbs of the darts are pointing downward and outward. In a space above the sheath lie the fleshy palpi. The delicate attachment between the sting and the organs of the abdomen is here indicated, for only a small portion of the sting, in comparison with its size, has any connection with parts in the abdomen. This accounts for the ease with which the sting is torn from the abdomen when the barbs become imbedded after a thrust of the darts is made.

Stinging Insects. — The stinging insects belong to the order Hymenoptera, suborder Aculeata, and are best known as the ants, bees, and wasps, in which the females of all species are provided with a specialized ovipositor known as a sting, more or less well developed for piercing the skin of higher animals or other insects. The sting is used either as an organ of defense or offense, in the latter case often to procure food for the young.

The principal aculeate Hymenoptera are divided into the following superfamilies: viz.: Formicina, the true ants; Sphecina, the digger wasps; Vespina, the true wasps; and Apina, the bees.

The superfamily Formicina includes the true ants, which are divided into three or more families, Formicidæ, Poneridæ, and Myrmicidæ. One of the most formidable stinging ants in California is *Pogonomyrmex californicus* Buck. This ant will not only attack humans but also smaller domesticated animals. Thus hog raisers in the Imperial Valley, California, report many pigs killed by ants, one farmer reporting a loss of 400 small pigs during one year and another 100 to 150 during a period of three years, — all killed by ants.

Ants of this species are very abundant in the Imperial Valley, and it is a matter of common observation to see a small pig walk leisurely upon an ant mound and suddenly begin to kick and squeal, due to the terrific attack of the myriads of ants rushing forth from the nest. The writer has meager experimental evidence to deny the popular opinion above stated. The pig is certainly very uncomfortable during the attack, but experimental evidence of paralysis and death due to the ants has not been secured. However, much more work needs to be done to safely deny the statements of practical hog raisers.

FIG. 216. — A velvet ant (Mutilla), also known as a "cow killer." × 2.2.

The ants may be destroyed by applying kerosene to the nests, using a funnel or hollow rod to reach the deeper parts; potassium cyanide in liquid form may also be used, but great care must be exercised both in the preparation and application of the same owing to its very poisonous nature.

Among the Vespina, the best-known stinging species belong to the family Mutillidæ, the velvet ants, also known as the woolly ants, cow killers, etc. (Fig. 216). The velvet ants are covered with hair and the body is commonly banded with two or more strongly contrasting colors. There are very many species of Mutillids, most of which measure from $\frac{1}{2}$ to 1 inch in length. A very common species in the central states of the United States is *Sphærophthalmia occidentalis* Linn., a black species with a scarlet band. This species is very common on the beach sands of Lake Erie, causing bare-foot bathers much distress.

Many of our large dusty yellow to cinnamon colored species belong to the genus Mutilla and are commonly called " cow killers " (Fig. 216). These occur abundantly among dry leaves along the roadside or bypaths in the woods.

To the Vespina also belong the yellow jackets or hornets, *Vespa maculata* Linn., and other species which build large nests in the branches of trees, also the mud daubers *Pelopæus cementarius* Drury, *Polistes pallipes* Lep., and *Polybia flavitarsis* Sauss., *et al.* These species with their relatives belong to the family Vespidæ, and all have a well-developed sting which may be used on the least provocation.

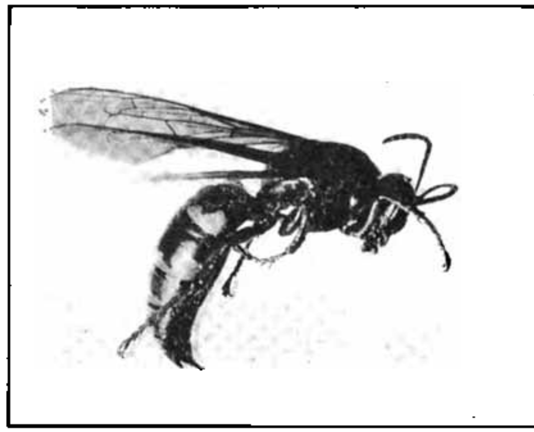

Fig. 217. — A digger wasp (*Sphecius speciosus*). × 1.1.

Of the solitary wasps belonging to the superfamily Sphecina, the great digger wasp or " cicada killer," *Sphecius speciosus* Say (Fig. 217), is the most formidable. This species, a member of the family Bembecidæ, is nearly an inch and a half in length, is black with yellow segmentally arranged partial bands on the abdomen. This wasp easily brings to earth very large cicadas, carries its prey to a previously prepared burrow where eggs are deposited and the larvæ develop in the cicada.

Underground wasps' or hornets' nests may be treated successfully with carbon bisulphide, while sulphur fumigation or thorough spraying with kerosene will suffice to destroy the nests of wasps built in the branches of the trees. Night treatment is suggested.

The true bees belong to the superfamily Apina, the honeybee *Apis mellifera* Linn., a member of the family Apidæ, and the bumblebee *Bombus fervidus* Fabr. and others belonging to the family Bombidæ.

Spiders

Class Arachnida — Order Araneida

Characteristics of the Araneida. — All spiders belong to the order Araneida in which the abdomen is sac-like and unsegmented, joined to the cephalothorax by a slender pedicel. According to Comstock [1]

[1] Comstock, John Henry, 1912. The Spider Book. Doubleday, Page & Co. xv + 731 pp.

the cheliceræ are usually claw-like, "folded back into a groove in the basal segment, like the blade of a pocketknife into a handle," *i.e. uncate;* or they may be pincer-like (*chelate*), "there being a prolongation of the first segment which is opposed to the claw." The pedipalps are more or less leg-like. The four pairs of legs are all fitted for walking. There are usually present eight eyes but these may be reduced to six, four, two or none. The respiratory organs of spiders are either *book lungs* or *tracheæ,* or in most species a combination of the two. The book lungs are sacs which open on the ventral side of the abdomen by means of slit-like spiracles. Within each sac there is a series of lamellate folds. The tracheæ are far less developed than in insects and are much more localized.

The Araneida are divided into more than thirty families.

Spider Venoms. — All spiders secrete venom by means of which they kill their prey. The venom glands are located in the anterior portions of the cephalothorax and are two in number. "Each gland discharges its product through a long slender duct which opens near the tip of the claw of the chelicera of the corresponding side of the body. This opening is so placed that it is not closed by the pressure of the bite, but allows the venom to flow into the wound. In the tarantulas each gland is situated in the basal segment of a chelicera. The glands are sac-like in form; the lumen of the sac serves as a reservoir of venom; the wall is composed of excreting cells, supported by a layer of connective tissue, and there is a layer of muscle fibers surrounding the sac" (Comstock).

While spider venom is very destructive to the life of insects upon which spiders prey, there is little evidence (with certain exceptions) to indicate that this venom is injurious to man. Most of our so-called spider bites are traceable to other sources, particularly cone-noses (Reduviidæ). Comstock (1912, *loc. cit.*) has given much attention to this matter and has come to the conclusion that there are no spiders that need be feared in the northern part of the United States at least, and in the South there is only one dangerous genus, *Latrodectes.* As to the so-called tarantula (Heteropoda) which is brought to the North in bunches of bananas Comstock has the following to say: "This, however, although a large spider is an inoffensive one. Mr. John T. Lloyd informs me that he has collected scores of specimens of this species with his hands in Samoa, where it is abundant, and has never been bitten by it."

The Hourglass Spider (*Latrodectes mactans* Fabr.), also known as the "black widow" or "shoe button" spider, is a medium-sized, glossy black, naked spider. The females measure from one to one and a fourth inches in length over all, while the males are less than an inch in length. The abdomen is globose, marked ventrally with brick-red triangular spots (Fig. 218). These spots vary in arrangement, — often two of these touch base to apex, or apex to apex, not unlike an hourglass in outline, or there may be four, roughly arranged like a Maltese cross; in some individuals only one spot may be seen. The males and immature females are variously striped and spotted with lighter markings. The species belongs to the family Theridiidæ.

Latrodectes mactans occurs quit ecommonly in California and the South, also the West Indies, Madagascar, New Zealand and Algeria,

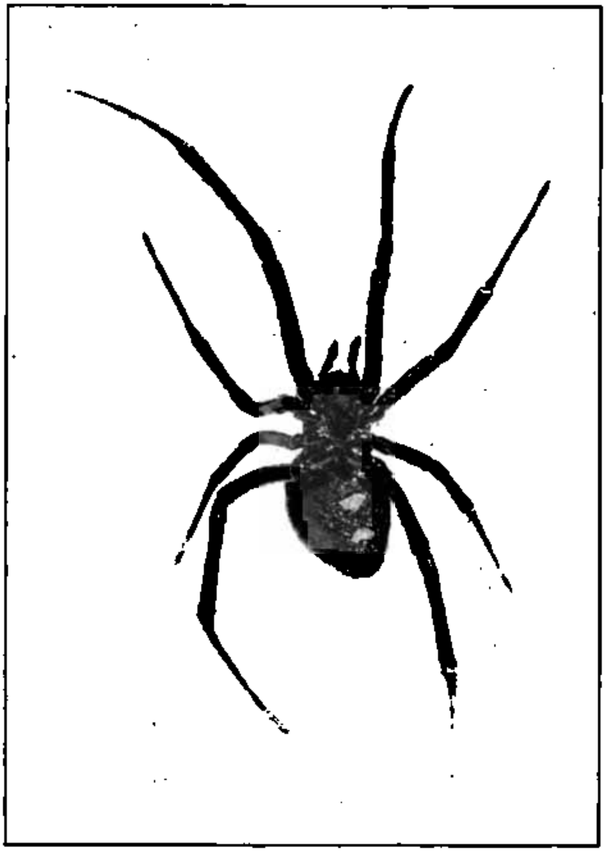

FIG. 218. — A venomous spider, *Latrodectes mactans*. × 3.

and has the reputation of being extremely venomous. Sundry specimens have been sent to the writer at various times, and occasional reports of its having caused dangerous and even fatal illness in California have been made, but unfortunately very little experimental evidence seems to be available.

An account of a fatal case in North Carolina is given by Packard and Howard,[1] viz.: An employee (farm laborer engaged in hauling wood) of Mr. John M. Dick is reported to have been bitten by a black spider

[1] Packard, A. S., and Howard, L. O., 1899. A contribution to the literature of fatal spider bites. Insect Life, Vol. 1, No. 7, pp. 204–211.

with a red spot on it at about 8.30 o'clock A.M., dying of the effects about fourteen hours later, *i.e.* between 10 and 11 o'clock P.M. The victim is said to have felt something crawling on his neck, and as he brushed it off it bit him very severely, causing very great pain. The cause was described as being a black spider with red spots. An examination of the neck revealed ten little white pimples, all of which could be covered with a one-dollar silver coin; no puncture was seen. There was no swelling, but the neck, left breast and arm were so hard that no impression could be made with the thumb. The man complained of pain running through his entire body. It should be noted that the man was perfectly healthy. By one o'clock the pain had settled in his bowels and shortly thereafter he was attacked with spasms. About four o'clock spasms recurred and the patient lapsed into unconsciousness and remained so until death.

In the same paper the authors refer to the investigation of Dr. Graells, appointed by the Academy of Medicine and Surgery at Barcelona in 1833 to investigate the reported venomous nature of the "Malmignatte" of southern Europe (*Latrodectes malmigniatus* Walck). Graells reported the following symptoms:

"A double puncture surrounded by two red circles, which unite, together forming an edematous areole which marks the seat of a tumor which develops later. The pain extends and soon occupies the length of the bitten limb, and often reaches the axillary or inguinal glands, according to the limb bitten. These glands tumefy and become painful and the skin between them and the bite becomes marked with livid spots which seem to follow the course of the lymphatic vessels. The pain continues, reaching the body even to the abdominal and thoracic cavities, with a sensation of burning heat, strong constriction or soreness of throat, tension of the abdomen, tenesmus, and extreme headache, which makes itself felt along the spinal column; soon followed by general convulsions, more particularly in the extremities, followed by insensibility, especially in the feet, which are ordinarily livid, while the whole body is swollen. This imposing array of symptoms brings about a very marked low spirit on the part of the patients, indicated by their expressions of despair, of profound affliction, or fear concerning the return of the health, for they believe themselves threatened with approaching death.

"They continually change from place to place in their bed, giving utterance to sighs and plaintive cries, carrying their hands to their heads mechanically, or they say that they feel their brain pricked by pins. The face is sometimes red and burning or others pale. The difficulty of respiration is marked, the pulse is very low, quick, irregular, the skin cold and rather moist from an abundant cold and viscid perspiration; at the same time the patient complains that his bowels are burning and asks for fresh water. In some cases the sight is almost totally obscured, and conjunctiva injected; in others the voice becomes weakened, and perhaps a ringing in the ears becomes very marked. Sometimes livid spots appear over the whole body. The intensity of these symptoms varies according to the susceptibility of the individual, to the strength of the *Latrodectes*, and also the number of bites which the patient has received.

"Recovery comes sooner or later according to the strength of the patient, the energy of the remedies, and the promptness of their effect. In all cases it is announced by the perspiration, which from cold and viscid becomes warm and vaporous; by the quickening and regularity of the pulse; by increasing facility in respiration and urination; by the cessation of the inflammation of the glands and of the aching in the brain and spinal cord, which passes into a sort of lethargy which may be more the effect of the laudanum given than a symptom of the disease."

In many respects the above symptoms apply to the two cases reported to the writer by the late Mr. Charles Fuchs, Curator of Insects, California Academy of Science; however, the local effects in these two cases were very much more severe.

According to Comstock (1912, *loc. cit.*), Merriam (1910) in "*The Dawn of the World, Myths and Weird Tales told by the Mewan Indians of California*," the Northern Mewuk says: "Po'ho-noo the small black spider with a red spot under his belly is poison. Sometimes he scratches people with his long fingers, and the scratch makes a bad sore. . . . All the tribes know that the spider is poisonous and some of them make use of the poison." The latter states also that the California Indians rank this spider with the rattlesnake as poison, and mash the spider to rub the points of their arrows in it.

Habits and Life History of *Latrodectes mactans*. — This spider occurs, when in its geographical range, not uncommonly in old outbuildings, old barns, stables, woodpiles, etc. It spins a rough web in which it catches its prey, mainly flies and other insects. It is an exceedingly aggressive species, as the writer has observed in the several grown individuals under observation at various times in the laboratory. The egg cocoons (Fig. 219) are spun during the summer, and are well protected by the web and carefully guarded by the female. Each egg cocoon contains three hundred, more or less, rather large eggs. The incubation period in observed cases at a maintained temperature of 27 ± 1° C. was about thirty days, — for example a spider spun her egg cocoon during the night of July 17, the eggs hatching during the night of Aug. 13. Seven egg cocoons were spun by one spider, but the eggs contained in the seventh did not hatch.

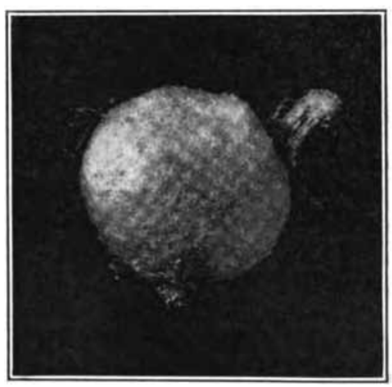

Fig. 219. — Egg cocoon of *Latrodectes mactans*. × 2.

The young spiders (Fig. 220) are gray, quite unlike the adult in this respect, and are very active, attacking plant lice, etc. at once. The first molt takes place within a week, followed by numerous molts at intervals of a week or more. The young spiders grow darker with each molt, with the appearance, however, of creamy white lines or spots dorsally on the abdomen. The reddish ventral markings appear within a month ordinarily. Growth is very rapid during the rest of the summer and autumn, but maturity is not reached until the following spring or early summer.

Tarantulas. — The term *tarantula* is applied to the very large spiders belonging to the Family Aviculariidæ occurring in California and other tropical and subtropical climates. The best-known species in California is *Eurypelma* (*Mygale*) *hentzii* Girard, also known as a bird spider, as is *Avicularia californica* Banks. While these spiders are much dreaded there is little or no evidence to warrant this fear. The common trapdoor spider of California is *Bothriocyrtum californicum* Cambridge, also greatly feared by many persons.

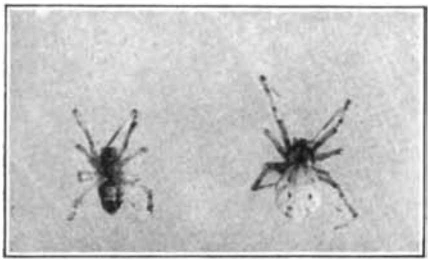

FIG. 220. — Young stages of *Latrodectes mactans*. Left, ventral view, showing reddish hourglass-like marking on abdomen; right, dorsal view, showing white abdomen with dark markings. × 3.

The term *tarantula* was first applied to an European species, *Lycosa tarentula*, which according to Comstock does not belong to the spiders to which this term is applied in America.

To the bite of *Lycosa tarentula* is referred the hysterical disease known as *tarantism* said to have been common in southern Europe in the Middle Ages.

The following account of *tarantism* is taken from the Cambridge Natural History, Vol. IV, p. 361: "The bite of the spider was supposed to induce a species of madness which found its expression — and its cure — in frantic and extravagant contortions of the body. If the dance was not sufficiently frenzied, death ensued. In the case of survivors, the symptoms were said to recur on the anniversary of the bite. Particular descriptions of music were supposed to incite the patient to the excessive exertion necessary for his relief; hence the name 'Tarantella.'

"In the middle ages epidemics of 'tarantism' were of frequent occurrence and spread with alarming rapidity. They were seizures of an hysterical character, analogous to the ancient Bacchic dances, and quite unconnected with the venom of the spider from which they took their name. The condition of exaltation and frenzy was contagious, and would run through whole districts, with its subsequent relapse to a state of utter prostration and exhaustion. The evil reputation of the Tarantula appears to have exceedingly little basis in fact."

VENOMOUS TICKS

Class Arachnida, Order Acarina

Ticks producing local or systemic disturbances by their bite alone are known in both families, Ixodidæ and Argasidæ (see Chap. XVIII), though more commonly in the latter.

Ordinarily little or no injury results from the mere bite of an Ixodine tick, — the writer has known of *Dermacentor occidentalis* Neumann and *Dermacentor variabilis* Say to remain attached to a person for days without causing great inconvenience and occasionally quite unobserved by the host. However, Nuttall (1911, *loc. cit.*, p. 133) records a number of cases cited by other authors in which the bite of *Ixodes ricinus* Linn. has caused serious consequences, notably a case described by Johannessen of a " boy where the tick's body was removed but the capitulum remained embedded in the skin at the back of the head. Swelling followed at the point of injury, accompanied by headache, stiffening and cramps in the muscles of one side, partial loss of memory and polyuria; the pupils became dilated, etc. The boy made a slow recovery." Blanchard is quoted by the same author as stating " that accidents of a grave character occasionally follow *ricinus* bites, the wound serving as a center from which infection may spread to the rest of the body."

Quite a number of species included in the Family Argasidæ are known to cause more or less serious consequences by their bites, notably *Ornithodorus moubata* Murray, *O. coriaceus* Koch, and *Argas persicus* Neumann.

Ornithodorus moubata Murray (see Chapter XVIII) has been reported repeatedly as causing marked consequences by its bite. Wellman as quoted by Nuttall (1908, *loc. cit.*, p. 98) " states that the bite is very painful, the swelling and irritation (especially in Europeans) not subsiding for days. The wheals are hard, raised and swell most disagreeably if scratched, and this even a week after being bitten. The bite of young ticks (nymphæ) is said by the natives to be more severe than that of the adults."

Ornithodorus coriaceus Koch. — The attention of the writer has been repeatedly called to a very venomous species of tick commonly known as the "Pajaroello bug" occurring in isolated sections of California and Mexico. Reports invariably indicate that the bite of a single individual produces very severe and often grave results. In conversation with natives it was learned that this creature was more feared than the rattlesnake. Many harrowing tales are told regarding the loss of an arm or leg or even death due to the bite of this tick. No doubt much of this is greatly exaggerated; however, the infected bite might easily lead to grave consequences. Mr. W. L. Chandler, a graduate student in the University of California, has given the writer an accurate account of two bites which he suffered while stationed in the San Antone Valley (California). The first bite was received July 2, 1912. He experienced a sharp pain on the left arm and upon rolling up his sleeve discovered a large tick, partly engorged, attached to the upper arm in front. He dislodged the tick and sucked the lesion. The lesion when first discovered showed a small dark purple ring surrounding a bright red spot, the point of attachment. The discoloration disappeared in a short time, but the arm was " highly irritable for two or three days and at the point of attachment a minute clear scab formed." The tick proved to be a "pajaroello."

The second bite took place July 16 while seated in a thicket of willows (the first bite took place while riding over a brush-grown hill), and in this case the sharp pain involved the left leg. An almost fully engorged tick (again a pajaroello measuring about $\frac{3}{4}$ of an inch in length and about $\frac{1}{2}$ inch in width was removed from just above the shin. Once more a bright red spot was visible at the point of attachment, surrounded by an irregular purple ring about three-fourths of an inch in diameter. In about an hour the leg began to swell in the vicinity of the lesion, and in about three hours the entire lower leg was tremendously swollen. The coloration about the point of attachment had widened considerably, was puffy and a clear lymph exuded freely from the lesion. The young man lanced the leg, causing the blood to flow freely, and treated the wound with crystals of potassium permanganate, binding the leg with cotton and gauze. During the following night he reports experiencing a general disagreeable feeling, the entire lower leg "irritable and numb." On the following day the bite on the arm became irritable again, and was treated as had been the leg, fearing bad results. For several weeks both lesions exuded a clear lymph from beneath an "oily-looking, transparent, red mottled scab" which remained in evidence for two or three months.

Chandler reported these ticks very numerous in some localities, having counted as high as six within half an hour crawling over a saddle blanket placed on the ground. Their presence and number seemed to be determined by the presence of cattle, although ticks were found where there were no cattle but in places which were evidently favorite haunts of large wild animals.

Experiments with the Pajaroello. — A number of specimens of *Ornithodorus coriaceus* were collected in the San Antone Valley and at Newman, California, for purposes of experimentation and study of life history. In coöperation with Dr. W. A. Sawyer and Messrs. S. W. Newman and W. L. Chandler, the writer conducted a number of experiments particularly with reference to the bite. In one of these experiments a mature female tick (*Ornithodorus coriaceus*) was permitted to bite a nearly full-grown monkey (*Macacus rhesus*) twice with an interval of sixteen days intervening between the two bites. The tick was applied at 9:42 A.M. Dec. 10, 1913 and began sucking blood at 9:43, one minute later, becoming engorged and falling off at 10:21 A.M., a period of 38 minutes. At 10:30 a few minutes after the tick dropped off there appeared a deep red hemorrhagic area 2 mm. in diameter at the point of biting with a somewhat lighter area 10 mm. in diameter surrounding the central area. At 10:27 there was a black spot at the point of bite 1.5 mm. in diameter, the inner red hemorrhagic area measuring 4 mm., with a yellowish white area surrounding this 8×6 mm., and an outer red petechial area 15×13 mm. No general symptoms were noted. As shown in Fig. 221 the lesion reached its greatest expanse the following day when the following measurements were taken:— dark purple spot 2 mm. in diameter (a very dark red scab); the inner red area 6 × 5 mm., the yellowish white area 20 × 12 mm., the outer area 48 × 23 mm. and fading. The yellowish white area including bite was slightly swollen. By Dec. 14, *i.e.* four days after the bite was received, the ecchymosis had entirely disappeared; by Dec. 16, six days

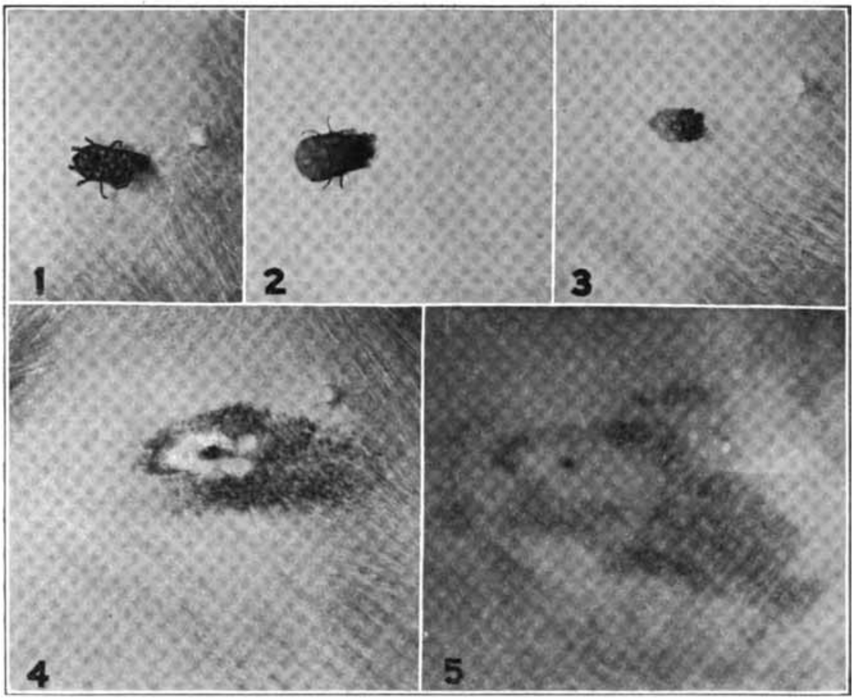

FIG. 221. — Showing venomous tick (*Ornithodorus coriaceus*) and lesion produced by same on skin of a monkey. (1) tick on skin before attaching; (2) tick attached and fully engorged; lesion appears as dark shadow at anterior end of tick; (3) shows lesion within a few minutes after tick has dropped off; (4) lesion at expiration of five hours; (5) lesion at expiration of twenty-four hours. (For description and extent of areas see text.) × .7.

after the bite, the lesion was entirely gone but for a slight pigmentation, a thickened reddish area measuring 5 × 3 mm. and a small scab 2 mm. in diameter.

The monkey remained normal throughout the experiment as regards temperature, weight, blood count and general condition.

The second bite was received by the same animal on Dec. 26, the tick being applied at 9:43 A.M., taking hold at 9:44 A.M., and dropping off fully engorged at 9:55 A.M., requiring but 11 minutes to engorge. The history of the second bite follows that of the first very closely, except for the extent of the lesion, which was greater, *i.e.* 70 × 31 mm. In order to note any manifestations on the part of the first lesion, the second bite was located near the opposite nipple. No change was observed.

Fig. 222. — Showing *Ornithodorus coriaceus* just backing away from her eggs recently deposited in the sand. Note the protective coloration of the tick. × 5.

The lesion produced by the second bite had disappeared by December 31, *i.e.* five days after the bite, except for a slight thickening 3 mm. in diameter and a slight white scale at the center. Again the monkey had remained normal, except for a slight increase in the count of white blood corpuscles, which rose from 7400 at the time of the bite to 13,900 by noon of the same day, going down again to 7300 by 5 P.M.

Life History of *Ornithodorus coriaceus*. — The pajaroello deposits large plum-colored spherical eggs (Fig. 222). In the laboratory these are deposited on the sand in slight depressions. There are commonly four to seven layings at intervals of from several days to several weeks during the months of May to July, inclusive (as early as February under laboratory conditions), and the female is known to deposit eggs for at least two successive seasons. The number of eggs observed per laying has been 61 to 323, with a total of from 747 to 1158 for one season. The incubation period at a maintained temperature of from 24° to 26° C. is from 19 to 29 days, with an average of about 22 days.

The larvæ (Fig. 223) are very active, scattering quickly and attaching readily to a host, particularly rabbits. Experimentally the human has also served as a larval host. The ear of a rabbit apparently affords a most satisfactory point for attachment. The larva remains attached to the host for a period of about seven days, becoming quite globular and much enlarged.

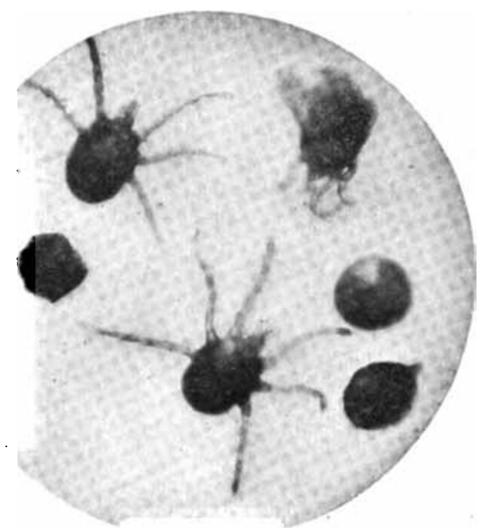

FIG. 223. — Showing egg of *Ornithodorus coriaceus* and larvæ of the same in the act of emerging; also two fully emerged individuals. × 14.

Under favorable conditions the tick becomes sexually differentiated after the fourth molt, requiring about four months to reach this stage. Others have not become sexually differentiated with five molts. Ordinarily the tick molts once for each engorgement, but there may be two molts between feedings.

Even though sexual differentiation is accomplished during the course of one summer, there seems to be little evidence at present that there is more than one generation per year.

Fully developed adult ticks were brought into the laboratory September 21, 1913, having been in captivity in the same stage four months previous and were still active and eager to bite January 1, 1915, a period of about 20 months. No molts had taken place during this time, notwithstanding the fact that full engorgement had occurred repeatedly and many eggs had been deposited.

Remedies for Tick Bites. — For the bite of *Ornithodorus moubata,* Wellman (in Ms. according to Nuttall, 1908) "recommends prolonged bathing in very hot water, followed by the application of a strong solution of bicarbonate of soda, which is allowed to dry upon the skin. He states that this treatment is comforting. For severe itching he advises smearing the bites with vaseline which is slightly impregnated with camphor or menthol. Medical aid should be sought when complications arise."

Scorpions

Class Arachnida, Order Scorpionida

Characteristics of the Scorpionida. — The most striking characteristics of the scorpions are, first, the formidable pedipalps terminating in strong lobster-like chelæ; second, the long tail-like postabdomen terminating in a bulbous sac and sting (Fig. 224). "The cephalothorax is compact and unsegmented; the abdomen is broadly joined to the thorax . . . consists of seven segments, and a slenderer tail-like division, the postabdomen or cauda, consisting of five segments. . . . The cephalothorax bears a pair of eyes near the middle line, the median eyes, and on each side near the cephalolateral margin a group of from two to five, the lateral eyes. A few scorpions are blind. . . . Scorpions breathe by means of book-lungs, of which there are four pairs, opening on the lower side on the third to the sixth abdominal segments. . . . The sexes of scorpions differ in that the male has broader pincers and a longer postabdomen. Scorpions do not lay eggs, the young being developed within the mother; after the birth of the young, the mother carries them about with her for some time, attached by their pincers to all portions of her body. . . . Scorpions live in warm countries. They are common in the southern portion of the United States, but are not found in the North. They are nocturnal,

Fig. 224. — A scorpion, *Hadrurus hirsutus.* × .6.

remaining concealed during the day, but leaving their hiding places at dusk. . . . They feed upon spiders and large insects, which they seize with the large chelæ of the pedipalps and sting to death with their caudal poison sting" (Comstock).

The order Scorpionida is divided into six families of which there are four in the United States, separated according to Comstock (1912, *loc. cit.*), viz.:

A. Only one spur at the base of the last tarsal segment of the last pair of legs, and this is on the outside . . . . *Scorpionidæ*

AA. One or two spurs on each side at the base of the last tarsal segment of the last pair of legs.

- *B*. From three to five lateral eyes on each side.
  - *C*. Sternum triangular; usually a spine under the sting *Buthidæ*
  - *CC*. The lateral margins of the sternum nearly parallel; sternum usually broader than long; no spine under the sting *Vejovidæ*
- *BB*. Only two lateral eyes on each side . . . . *Chactidæ*

Over three hundred species of scorpions are known, of which over sixty occur in the United States, of which the following are characteristic:

Isometrus maculatus Linn., known as the spotted Isometrus, is widely distributed in tropical and sub-tropical countries. This species is described by Comstock as follows: "A dirty yellow species marbled and flecked with black. The body is thin and slender. In the female the postabdomen is usually about as long as the rest of the body; in the male, it is often twice as long. The hand is long and thin, thinner than the tibia of the pedipalp; the finger is from one and a half to two times as long as the hand. The combs[1] have from seventeen to nineteen teeth. The female grows to nearly two inches in length; the male to nearly three inches.

Centrurus carolinianus possesses a spine or tubercle under the sting; body striped with black and yellow; a small pale median spot on the anterior border of the cephalothorax; legs pale yellow; postabdomen pale. Occurs in the Southern states (Comstock).

Hadrurus hirsutus Wood is a very large and hairy species found in the Southeast. The penultimate tarsal segment of the first three pairs of legs is furnished with long hairs on the back (Comstock).

Vejovis carolinus, a reddish brown species, occurs from South Carolina to Texas.

Scorpion Sting. — The "aculeus" or sting of the scorpion is located terminally on the final bulbous segment. The bulbous segment incloses a venom-containing vesicle connected with the sting which terminates in a hollow needle-like point. The sting curves downward

[1] The combs of a scorpion are located ventrally, originating from the "sclerite on the middle line of the body" just anterior to the first segment of the postabdomen. Each comb, of which there are two, is provided with so-called teeth.

when the "tail" is extended, but upwards and forwards when the scorpion poises for attack or defense, the entire tail-like postabdomen being curved dorsally and forwards. The victim is struck quickly and repeatedly, the thrust being made quite near the head of the scorpion.

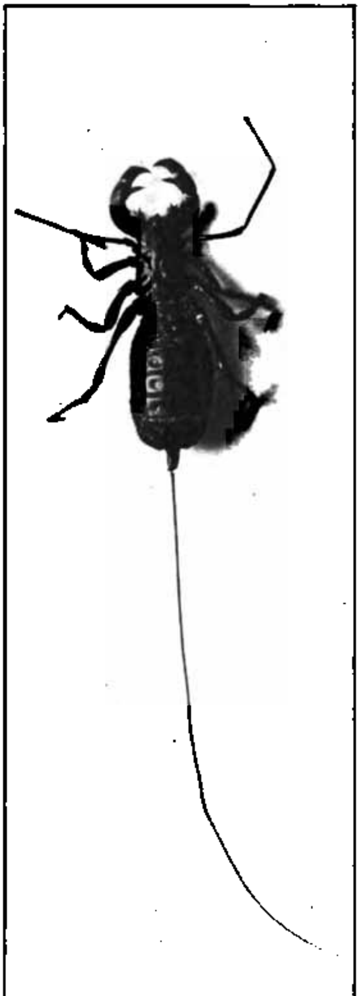

Fig. 225. — Whip scorpion (Pedipalpida) *Mastigoproctus giganteus*. ×.8.

Scorpion stings are quite common in California; ordinarily most persons pay no more attention to the sting of a scorpion than to the sting of a wasp. The pain produced is instant and quite penetrating. In some instances the wound is quite severe and systemic disturbances may result. Fatal cases rarely if ever occur.

Treating the wound promptly with ammonia ordinarily brings prompt relief.

Whip Scorpions

Class Arachnida, Order Pedipalpida

Characteristics of Pedipalpida. — The Pedipalpida resemble scorpions in some respects in that the pedipalps are similar. The first pair of legs is elongated and tactile, while the last three pairs are ambulatory. The term "whip scorpion" is applied to the Family Thelyphonidæ, because the terminal end of the abdomen is provided with a long slender many-segmented appendage (Fig. 225). "Grampus" and "vinegerone" are also common names. The species are tropical and subtropical.

The whip scorpion, *Mastigoproctus giganteus*, occurs in southern California, mainly in sandy desert places where it burrows in the sand under débris. They are commonly regarded as poisonous, although they cannot sting, but may bite. The writer has found that the natives invariably fear this creature very considerably, but knows of no evidence to justify this attitude.

SOLPUGIDS

Class Arachnida, Order Solpugida

Characteristics of the Solpugida. — The solpugids are characterized in the Cambridge Natural History (Vol. IV, p. 423), viz.: "Tracheate Arachnids, with the last three segments of the cephalothorax free and the abdomen segmented. The chelicerae are largely developed and chelate, and the pedipalpi are leg-like, possessing terminal sense organs" (Fig. 226).

The general appearance is spider-like; they are very hairy, largely nocturnal, occurring in desert tropical regions. Though little is known about this interesting group, they are fairly common in certain portions of southern California, notably in the neighborhood of Salton Sea, where they are regarded as exceedingly venomous. The writer has been told that the presence of one of the animals in a watering trough would result in the death of any animal drinking from the same. There is evidently not the slightest foundation for this belief. Their bite is benign. Common names applied to this order are "Sun Spider" and "Wind Scorpion."

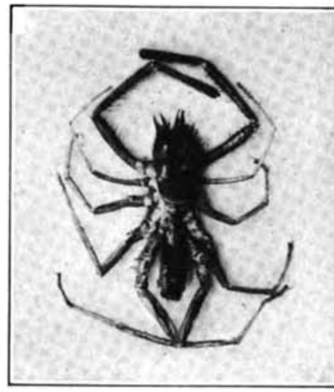

FIG. 226. — Sun spider (Solpugid), *Eremobates cinerea*. × 1.

The order is represented by a large number of species occurring only in tropical and subtropical countries, notably Africa. There are said to be only twelve species in the United States, all but one belonging to the two genera, *Eremobates* and *Ammotrecha*.

CENTIPEDES

Class Myriapoda, Order Chilopoda

Characteristics of Myriapoda. — The Myriapoda are worm-like animals with separate head, possessing antennae, and many fairly similar segments, each possessing one or two pairs of segmented appendages. Like the insects they are tracheated and for the most part terrestrial.

The class Myriapoda is divided into four or five orders of which the following are well known, viz.: Chilopoda, the centipedes, with only one pair of appendages to each segment; and the Chilognatha (Diplopoda), the Millipedes, with two pairs of appendages to each segment, *e.g. Julus nemorensis*, a so-called "thousand-legged worm."

Characteristics of Centipedes. — The Chilopoda have only one pair of appendages to each segment and are widely separated at the bases, the antennæ are many jointed, the genital pore is located on the terminal body segment. The larger species, at least, are carnivorous, feeding mainly on insects. Notwithstanding the confusing abundance of walking appendages the centipedes crawl very rapidly.

Unlike the Millipedes, which possess no organs of defense except glands which secrete an offensive odor, the Centipedes are provided with powerful poison claws located immediately ventral to the mouth, and connected by means of a hollow tube with large poison glands.

Fig. 227. — A venomous centipede. *Scolopendra heros.* × .66.

The larger species of Centipedes belong to the following genera: viz., Scolopendra, Lithobius and Geophilus, and may be over six inches in length, some are reported to be eighteen inches long.

Venomous Centipedes. — The larger centipedes are commonly regarded as very venomous, and it is said that their bite may be fatal to man. It is true that an insect captured by Scolopendra or Lithobius is killed almost instantly when the poison claws close upon it.

In southern California the large greenish centipede *Scolopendra heros* Girard (Fig. 227) is greatly feared. It measures from four to five inches in length and has a very formidable appearance. It is said that it not only punctures the skin with its poison claws, causing considerable pain, but also produces a "reddish streak where it has crawled upon the body." It is interesting to know that these animals are also markedly phosphorescent, which may possibly account for some of the phenomena produced on the skin. *Geophilus electricus* and *G. phosphoreus* are notable examples of phosphorescent species.

APPENDIX I

GENERAL CLASSIFICATION OF BACTERIA AND PROTOZOA

Differences in Methods of Study in Bacteria and Protozoa. — The lowest forms of animal life belong to the Protozoa, while the lowest forms of vegetable life belong to the Bacteria in a broad sense. Since the epoch-making discoveries of Pasteur and Koch, advancing the "germ theory" of disease, these organisms have been the objects of research in many lands and by many investigators, and distinct sciences, namely, Bacteriology and Protozoölogy, have been developed. The methods of study in the two branches are rather different, inasmuch as Bacteria may be studied in culture media, while the Protozoa ordinarily require different methods, *i.e.* are not as readily amenable to culture media. Calkins has stated this in the following clear terms: "The study of protozoa, even when possible to apply bacteriological methods, is fundamentally different from the study of bacteria, as at present carried on. The latter, dependent on growth conditions, colony formation, reactions to media, etc. are essentially physiological, and based upon the function of the organisms. The study of protozoa, on the other hand, is essentially morphological, or based upon the structures of the protozoan cell, and involves the changes in cell structures which an individual undergoes during various phases of vitality. Hence it becomes necessary first of all to know the life history of the protozoon, and the fundamental modification which its protoplasm assumes." The student of Medical Entomology should not only be familiar with general structures and life history processes, but also with the methods of study applied in the laboratory such as the preparation and use of culture media, animal experimentation, etc.

The Bacteria. — There are " only three principal types of bacteria, — the sphere, the rod and the spiral. Under normal and uniform conditions of life each breeds true, the spherical producing spheres and the rods, again, only rods." [1]

Classification. — The following classification after Migula,[2] adapted after Jordan, with the addition of examples in the transmission of which insects and arachnids are concerned, will serve as a general guide in locating certain diseases touched upon in the preceding chapters. Unfortunately, contrary to the statements made above, it seems necessary

[1] Jordan, Edwin O., 1908. Textbook of general bacteriology, 557 pp. W. B. Saunders Co.

[2] Migula. System der Bacterien, Jena, 1897 (after Jordan, *loc. cit.*).

to resort to a classification based on structural, instead of physiological, characters (Fig. 228).

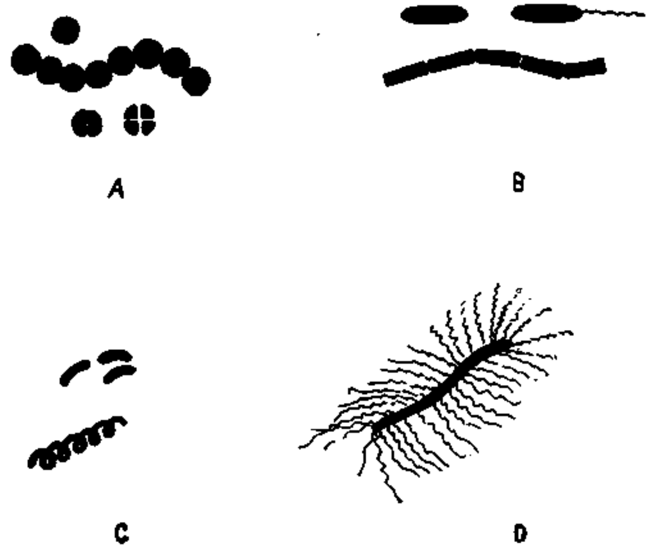

FIG. 228. — Illustrating types of bacteria. A. Sphere or coccus; B. Rod or bacillus; C. Spiral or spirillum; D. Example of higher bacteria. (Adapted in part after Jordan. Greatly enlarged.)

I. Cells globose in a free state, not elongating in any direction before division into 1, 2 or 3 planes . . . . 1. Coccaceæ

II. Cells cylindrical, longer or shorter and only dividing in one plane, and elongating to about twice the normal length before the division.

- *a.* Cells straight, rod-shaped, without sheath, non-motile, or motile by means of flagella . . . . 2. Bacteriaceæ
- *b.* Cells crooked, without sheath . . . . . . 3. Spirillaceæ
- *c.* Cells inclosed in a sheath . . . . 4. Chlamydobacteriaceæ

1. Coccaceæ

Cells without organs of motion

- *a.* Division in one plane . . . . *Streptococcus*
  - *e.g. Streptococcus erysipelatis* of erysipelas
- *b.* Division in two planes . . . . *Micrococcus*
  - *e.g. Micrococcus melitensis* of malta fever
- *c.* Division in three planes . . . . *Sarcina*

Cells with organs of motion

- *a.* Division in two planes . . . . *Planococcus*
- *b.* Divisions in three planes . . . . *Planosarcina*

2. Bacteriaceæ

Cells without organs of motion . . . . *Bacterium*

Cells with organs of motion (flagella)

- *a.* Flagella distributed over the whole body . . . *Bacillus*
  - *e.g. Bacillus anthracis* of anthrax
  - *Bacillus typhosus* of typhoid
  - *Bacillus pestis* of bubonic plague
  - *Bacillus tuberculosis* of tuberculosis

b. Flagella polar . . . . *Pseudomonas*

3. Spirillaceæ

Cells rigid, not snake-like or flexuous
- *a.* Cells without organs of motion . . . . *Spirosoma*
- *b.* Cells with organs of motion (flagella)
  1. Cells with 1, very rarely 2 to 3 polar flagella . *Microspira*
  2. Cells with polar flagella-tufts . . . . *Spirillum*

  e.g. Spirillum (*vibrio*) *choleræ* of Asiatic cholera

Cells flexuous (see also under Protozoa) . . . . *Spirochæta*

e.g. Spirochæta duttoni of African relapsing fever

4. Chlamydobacteriaceæ (higher bacteria)

Cell contents without granules of sulphur
- *a.* Cell threads unbranched.
  - I. Cell division always only in one plane . . . *Streptothrix*
  - II. Cell division in three planes previous to the formation of gonidia:
    1. Cells surrounded by a very delicate, scarcely visible sheath. (marine) . . . . *Phragmidiothrix*
    2. Sheath clearly visible (fresh water) . . . . *Crenothrix*
- *b.* Cell threads branched . . . . *Cladothrix*

Cell contents containing sulphur granules . . . . . . *Thiothrix*

The Protozoa

Classification of the Protozoa.[1]

Phylum Protozoa; Unicellular animals (Fig. 1)
- Subphylum Mastigophora. Flagella-bearing protozoa
  - Class zoömastigophora. Undisputed animal flagellates
    - Subclass Lissoflagellata without protoplasmic collars
      - Order Spirochætida
        - *e.g. Spirochæta duttoni* of African relapsing fever, carried by a tick, *Ornithodorus moubata*
        - *e.g. Spirochæta gallinarum* of poultry spirochætosis, carried by a tick, *Argas persicus*
        - *e.g. Treponema pallidum* of Syphilis
      - Order Trypanosomatida
        - *e.g. Trypanosoma gambiense* of African sleeping sickness, carried by a Tsetse fly, *Glossina palpalis*
        - *e.g. Trypanosoma brucei* of Nagana (disease of certain African beasts of burden), carried by a Tsetse fly, *Glossina morsitans*
    - Subclass Choanoflagellata. With protoplasmic collar
      - (No pathogenic species)
  - Class Phytomastigophora. With plant characteristics
    - (No pathogenic species)
- Subphylum Sarcodina. Protozoa with pseudopodia only
  - Class Rhizopoda. Pseudopodia without axial filaments
    - Subclass Amœbæa. With firm lobose pseudopodia
      - Order Gymnamœbia
        - *e.g. Entamœba histolytica* of tropical dysentery
  - Class Actinopoda. With supporting axial filaments
    - (No pathogenic species)
- Subphylum Infusoria. Motile organs, cilia; dimorphic nuclei
  - Class Ciliata. Without tentacles; always ciliated
    - Order Holotrichida

[1] Adapted after Calkins, including only groups of pathogenic importance.

e.g. Balantidium coli; causative organism of a type of dysentery known as Balantidiosis
Class Suctoria. With suctorial tentacles; embryos ciliated (No pathogenic species)
Subphylum Sporozoa. No motile organs; reproducing by spores
Class Telosporidia. Reproduction ends life of cell
Subclass Gregarinida. Lumen-dwelling sporozoa
Order Schizogregarinida
e.g. Ophryocystis
Order Eugregarinida
e.g. Monocystis
Subclass Coccidiidia. Cell-dwelling sporozoa
Order Tetrasporocystida
e.g. Coccidium tenellum (?) of Blackhead in turkeys
Subclass Hæmosporidia. Sporozoan parasites of the blood
Order Hæmosporida
e.g. Hæmamœba (Proteosoma) relicta of bird malaria in sparrows; in India carried by Culicine mosquitoes
Order Xenosporida
e.g. Plasmodium vivax of tertian malaria, carried by certain Anopheline mosquitoes
e.g. Babesia bigemina of Texas cattle fever, carried by a tick, *Margaropus annulatus*
e.g. Piroplasma hominis (doubtful or disproven) of Rocky Mountain spotted fever of human beings, carried by a tick, *Dermacentor venustus*
Class Neosporidia. Reproduction with continued life of cell
Subclass Myxosporidia. Spores with distinct capsules
Order Myxosporida
e.g. Myxobolus cyprini of pox disease of the carp
Order Microsporida
e.g. Nosema bombycis, causative organism of pebrine in silkworms

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