ARTHROPODS OF PUBLIC HEALTH SIGNIFICANCE IN CALIFORNIA

California Department of Public Health
Vector Control Technician Certification
Training Manual
Category C

ARTHROPODS OF PUBLIC HEALTH SIGNIFICANCE IN CALIFORNIA

Category C: Arthropods

A Training Manual for
Vector Control Technician's Certification Examination
Administered by the California Department of Health Services

Edited by

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of California

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PREFACE

Ongoing changes in Integrated Pest Management (IPM) technology as applied to vector surveillance and suppression has evolved into many changes affecting vector management strategies coupled with increased environmental protection legislation. Current views on control paradigms have necessitated the revision of the much outdated first edition of the technical manual entitled *Community Pest and Related Vector Control* (encouraged and promoted by Mr. Richard F. Peters, Chief, Bureau of Vector Control, California Department of Public Health), first published in 1969, edited by Joe E. Brooks and Thomas D. Peck. Revision of the second edition, 1975, Donald J. Womeldorf and Thomas D. Peck, Editors, had been “in-the-works” for the past several years. Both these publications included, in addition to information on the biology and control of invertebrate vectors of public health concern (other than mosquitoes), a comprehensive section on vertebrate vectors that also impact human health and welfare.

With the publishing of *Pesticide Application and Safety Training for Applicators of Public Health Pesticides*, by Michael W. Stimmann and Bruce F. Eldridge (1996), and *The Biology and Control of Mosquitoes in California*, edited by Stephen L. Durso, 1996 (this publication was preceded by *Manual for Mosquito Control Personnel, 1973*, Thomas D. Mulhern, Editor; Revised Edition 1975, entitled *A Training Manual for California Mosquito Control Agencies*, Thomas D. Mulhern, Editor; second printing 1976), it became obvious that the need for a further revision and “realigning” of the *Community Pest and Related Vector Control* was warranted. The decision was made to publish two separate reference/training manuals. This manual focuses on arthropod vectors, placing more emphasis on biology, public health significance, and integrated and innovative approaches to management technology. Sections on pesticide application and safety have been published separately as mentioned above. Information on vertebrate vectors would be deferred to a separate publication that will be titled *Vertebrates of Public Health Significance in California*, editorship has been assigned to Curtis L. Fritz.

This new manual on arthropod vectors entitled, *Arthropods of Public Health Significance in California* reflects that consensus and contains a total of 19 chapters that include information on epidemiology, arthropod vector biologies, diseases vectored in California, arthropod vector management, and safety protocols. The information contained in this publication is by no means complete. The editors encourage regular users of this manual to refer to the many other sources of information provided by the contributing authors at the end of each chapter, plus other new publications as they appear. Vector control professionals are continuously urged to seek additional information to enhance their experience and expertise.

The credits due to those that have assisted the editors with the final realization of producing and finally publishing *Arthropods of Public Health Significance in California* cannot be simply noted, instead a wholehearted *thank you* is truly deserved. To all of the contributing authors, we both want to extend our appreciation and *thanks* for bearing with us through the sometimes tedious editing process and midcourse changes that were necessary to place this publication in its proper perspective. Special recognition must be given to Minoo B. Madon for his singular efforts in initially contacting all of the contributing authors and tactfully conveying editorial recommendations and changes to preliminary drafts. Special recognition is also to be given to Justine Keller for her exceptional “journalistic” skill and producing the final edited galley for publication. James P. Webb, Jr. is to be given special recognition for providing his editorial services in proofing the final edited galley. Credit should be extended to the Publications Committee of the Mosquito and Vector Control Association of California (MVCAC) currently chaired by Jack E. Hazelrigg (previously chaired by Gilbert L. Challet, Charles H. Dill, and Stephen L. Durso, respectively). Continuing, Vicki L. Kramer, Chief, Vector-Borne Disease Section, California Department of Health Services, is to be commended for her continued patience and persistence with encouraging the editors to meet production schedules during the final two years of editing, producing, and finally publishing this manual. Mac Thompson, Continuing Education Coordinator for the Vector-Borne Disease Section, California Department of Health Services is to be commended for his assistance in the preparation of the final draft of this manual. A noted *thank you* is to be extended to Dennis Loughner for his cover illustration and artwork presented in Chapter 2 and Jon Miller for his artwork in Chapter 11. *Thanks* are due to Donald Eliason, former Executive Director, MVCAC, for guiding us through this project. Finally, a *very special thank you* for the most difficult task of formatting and styling the text must be acknowledged and given to Linda Sandoval, former Office Manager, MVCAC.

The editors also wish to recognize the efforts of the editors of the 1969 publication, Joe E. Brooks and Thomas D. Peck, and the following authors: Charles F. Homer, W. Douglas Jones, J. E. Brooks, Irma West, Minoo B. Madon, John Ruddock, J. W. Tilden, Donald D. Linsdale, George T. Okumura, Roy J. Pence, C. F. Homer, Robert E. Smith, Benjamin Keh, Allan M. Barnes, Donald J. Womeldorf, Keith F. Murray, William G. Waldron, Minoo B. Madon, and Millard R. Coale.

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In closing, we once again wish to remind our readers that this manual is to be used as a basic training manual and reference guide, which should be supplemented by additional reading of current publications.

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CHAPTER 1

EPIDEMIOLOGY OF VECTOR-BORNE DISEASES

Bruce F. Eldridge[1]

INTRODUCTION

Epidemiology is the study of human disease epidemics. An epidemic is an unusually large number of cases of a disease occurring within a short period of time. In general usage, epidemiology is simply the study of human diseases. Diseases may be caused by many things, including mechanical agents, chemical agents, vitamin deficiencies, and genetic problems. Diseases that are caused by microorganisms are called infectious diseases. Vector-borne diseases are infectious diseases in which the microorganisms that cause the symptoms are transmitted by insects or other arthropods. Therefore, the epidemiology of vector-borne diseases is the study of diseases, such as malaria, plague, murine typhus, St. Louis encephalitis, western equine encephalomyelitis, West Nile fever, and so on. However, since arthropods can be the direct cause of human diseases, as in the case of bee, wasp, or scorpion stings, epidemiologists and medical entomologists must be concerned with these situations as well. It is important to understand all of the factors that can lead to outbreaks of vector-borne diseases. Without this information, it is hard to predict, prevent, or control outbreaks. This chapter will review some of the basic principles of epidemiology, and some of the most important ecological factors that are related to outbreaks of various kinds of vector-borne diseases.

EPIDEMIOLOGICAL TERMS
(Figure 1-1)

As explained above, an epidemic is an unusually large number of cases of a disease in humans occurring within a short period of time. The term which should be used for an outbreak of a disease in animals other than humans is an epizootic. This term may even be applied to diseases of insects and other invertebrates. There are two important terms that are used to express the number of disease cases which are occurring. The incidence of a disease refers to the number of new cases within some time period. A year is often the frame of reference, and the incidence would then be described as the number of cases per year. The prevalence of a disease refers to the number of cases of a disease present in an area or human population unit at any given time. A typical expression of prevalence might be 50 cases per 100,000 population.

The constant occurrence of an infectious or disease-causing agent in a given geographic area in humans is termed “endemic”; in other animals this relationship is called “enzootic.”

Vector-borne diseases have three components in their natural transmission cycles: (1) a pathogen (etiologic agent), the actual cause of disease; (2) a host, the animal affected by the disease; and (3) a vector, an insect or other arthropod. To an epidemiologist, a vector may include other agents, such as contaminated clothing or water. Another term used frequently in epidemiology is parasite. A parasite is an organism that lives at the expense of another organism, for example, a flea living on a dog. Parasites include microbial pathogens that live inside the body of a host (endoparasites) and insects and other arthropods which inhabit the skin of hosts (ectoparasites). Some ectoparasites, such as ticks, are important vectors of human disease pathogens as well.

Diseases that affect only people are called anthroponoses. However, among vector-borne diseases, zoonoses are more common. A zoonosis is an infectious disease of nonhuman vertebrates that is secondarily transmissible to humans. Many vector-

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borne infectious diseases are zoonoses, and many zoonoses are vector-borne. However, there are some very important vector-borne diseases, such as malaria, that are not zoonoses and some important zoonotic diseases, such as rabies and hantavirus, for example, that are not vector-borne. Typhus is not a zoonosis even though other animals are susceptible to infection by the rickettsial pathogen causing the disease because the human body louse, the vector of typhus, usually will not feed on animals other than humans

Some other terms, which are used frequently in epidemiologic studies, are pathogenicity and virulence. Pathogenicity is the proportion of hosts that develop symptoms among those infected by a particular strain of pathogen. Virulence refers to the proportion of cases of infection that develop severe symptoms. Thus, viruses that cause the common cold probably have high pathogenicity but low virulence. In other words, most people infected with a cold virus will probably get a cold, but few will develop serious (life threatening) symptoms.

There is a set of epidemiological terms that refers to the presence of pathogens in the blood stream of infected hosts; all end in "-emia." For parasites, the term is parasitemia; for viruses, viremia.

METHODS OF TRANSMISSION

Arthropods can cause human diseases in a number of different ways. They can be the direct cause of diseases, in the case of scabies mites, or indirectly involved, as with fleas, which serve as intermediate hosts of the double-pored dog tapeworm, *Dipylidium caninum.* This tapeworm usually infects dogs, cats, and other animals that become infected after ingesting infected fleas, but young children can be infected as well as a result of coming in close contact with infected pets.

On a worldwide basis, the most serious threat to human health by arthropods is caused by the ability of various species to serve as vectors of disease-causing micro-organisms. Malaria, yellow fever, plague, and typhus are all examples of deadly human diseases caused by pathogens transmitted by arthropods. There are several different ways in which arthropods transmit microorganisms. These ways are reviewed in the following sections.

Mechanical Transmission. A number of human diseases are caused by microorganisms that are transmitted in various ways, including arthropod transmission. Typically, these are enteric diseases caused by bacteria and viruses,

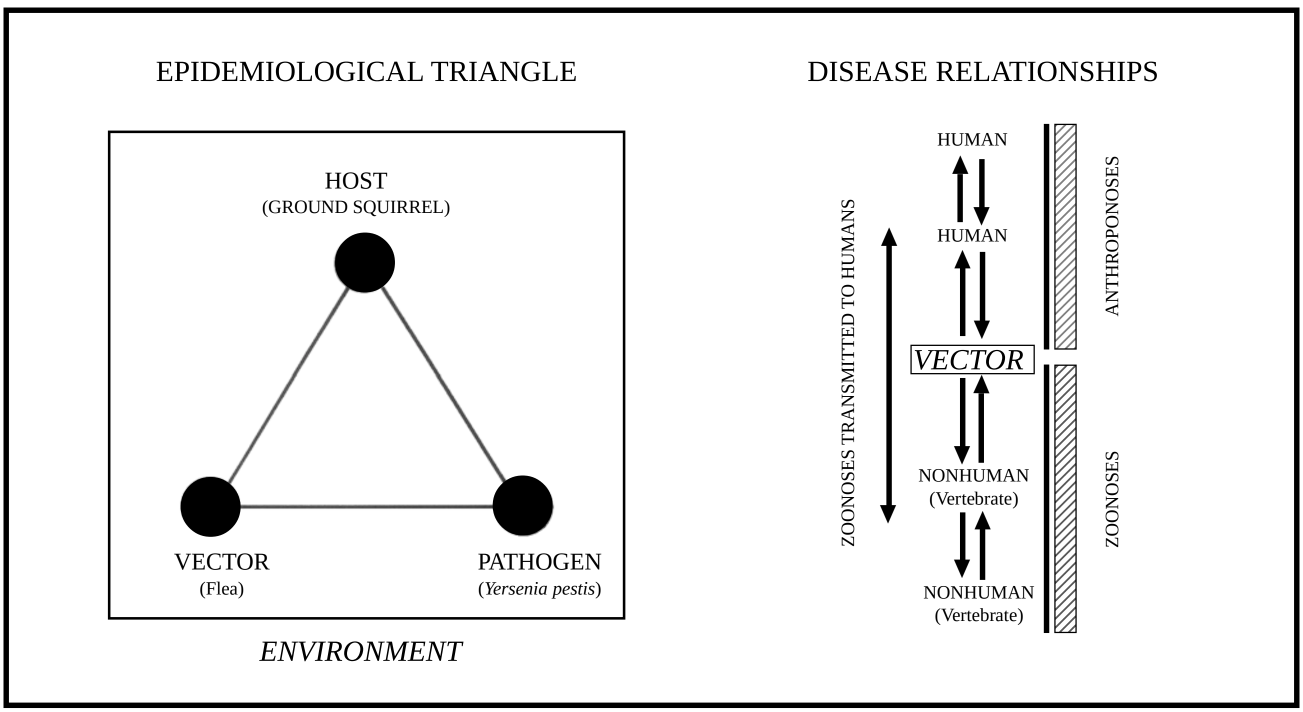

Figure 1-1. Vector-borne disease relationships.

such as shigellosis, salmonellosis, and cholera. There is no specific biological association between the pathogens and the arthropods. Transmission occurs mechanically when the pathogens adhere to body hairs, spines, sticky pads, or other structures of insects, such as flies, roaches, ants, and beetles. In the case of flies, transmission may be by regurgitation. Biting flies, such as horse flies and deer flies, may transmit pathogens mechanically in the course of biting with contaminated mouthparts. Nearly all mechanically transmitted diseases can also be transmitted in other ways (e.g., contaminated food and water).

Biological Transmission. When there is a strong biological association between the arthropod vector and the pathogen, the term biological transmission is applied. With biological transmission, there is usually no natural method of transmission other than by the arthropod vector. Malaria and yellow fever are two examples of diseases caused by organisms biologically transmitted by arthropods. Biological transmission can be broken down into three types:

a. Propagative transmission. In this type of transmission, the pathogen multiplies within the body of the vector, but does not undergo any changes in form. Most viral diseases fall into this category. Plague (a bacterial disease) is also an example.

b. Cyclical transmission. The only pathogens that are transmitted this way are the filarial nematodes. In this case, the parasites undergo several molts in the body of the vector, starting out as microfilariae and eventually becoming infectious larvae. However, no multiplication takes place within the body of the vector, and it is a “one in-one out” situation.

c. Propagative and cyclical transmission. This is the most complicated type of transmission because both multiplication and changes in the life form of the pathogen occur within the vector. Examples of this type of transmission are malaria and leishmaniasis, both caused by protozoan parasites.

Horizontal and Vertical Transmission (Fig. 1-2). Horizontal and vertical transmission describe the pathway a pathogen takes among vectors and hosts. Typical horizontal transmission involves the pathogen being transmitted by a vector to a host in a cyclical pathway (e.g., encephalitis virus between mosquitoes

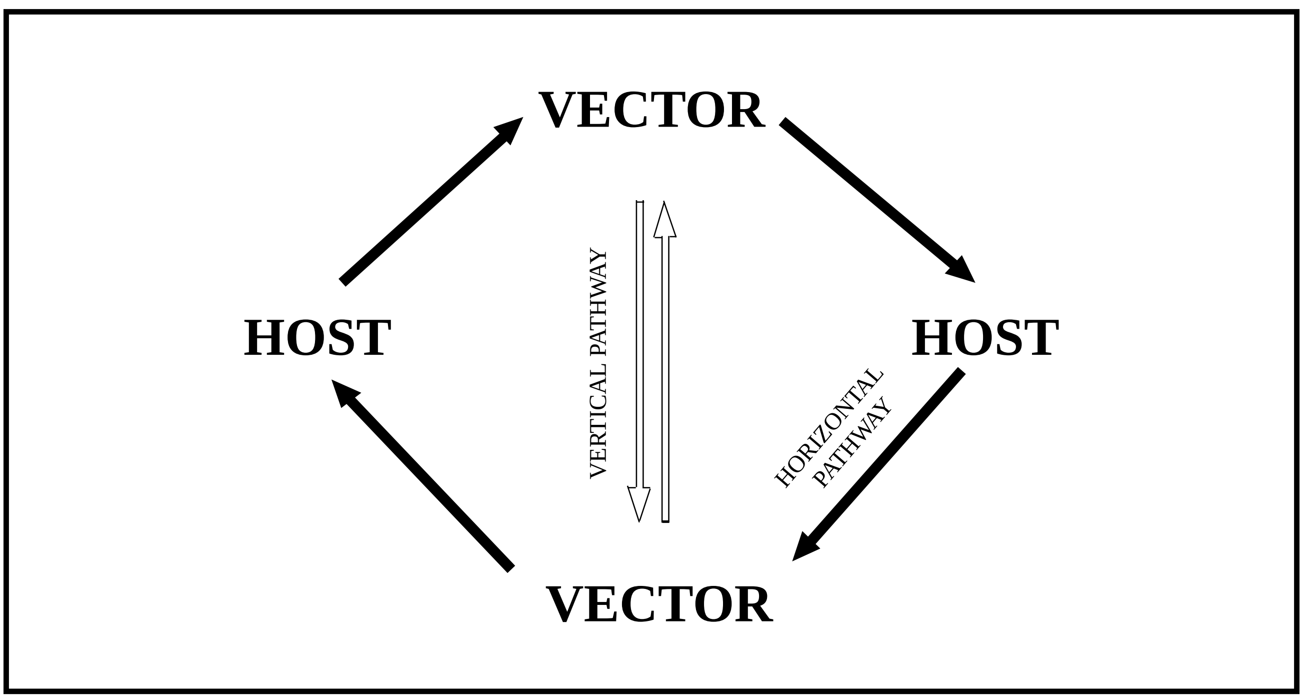

Figure 1-2. Horizontal and vertical transmission mechanisms.

and birds). Vertical transmission is more direct and does not involve a host, but occurs directly from infected mother/female to offspring. This process by which the offspring become infected (via infected ovaries/eggs) is termed transovarial transmission (TOT).

Vector Incrimination

It is very important to know which species of arthropod is serving as a vector of a particular disease pathogen. The process of making this determination is called vector incrimination, and is based on principles put forth many years ago, and described by the medical entomologist Herbert C. Barnett. Barnett (1956) presented a series of criteria, or methods, to be used to incriminate vectors of human disease pathogens. The criteria were adapted from the famous postulates developed by Robert Koch, a German bacteriologist, to prove that certain bacteria were the causal agents of particular human diseases. An adaptation of Barnett's postulates are presented in Table 1-1.

Scientists W. McD. Hammon and W. C. Reeves used essentially these same methods to show that *Culex tarsalis* was the primary vector of western equine encephalomyelitis and St. Louis encephalitis viruses in the Yakima Valley of Washington in the late 1930s and early 1940s. More recently, a number of workers applied these same postulates to the question of whether or not mosquitoes might transmit the HIV virus to human beings. It was concluded that such transmission was extremely unlikely.

VECTORIAL CAPACITY

Vectorial capacity describes the potential of a group of arthropods to transmit a given pathogen. The concept includes the susceptibility of an arthropod to infection by a given pathogen and the ability of that arthropod to transmit that pathogen (called vector competence). It also includes ecological and behavioral traits of vectors, such as longevity, dispersal, host preference, and abundance.

The main determinants of vectorial capacity and methods used to estimate them are discussed below.

Abundance

The abundance of vectors is one of the most important features of vectorial capacity for most diseases because it has a direct bearing on the probability of vector-host contact. As can be seen in Figure 1-3, the occurrence of peaks of vector abundance is very important. An important consideration in vector incrimination is deciding if these peaks coincide with peaks in human cases of a disease. In the example shown in Figure 1-3, the peak in the number of cases of Japanese encephalitis and the peak in mosquito abundance is separated by a time about equal to the incubation period of Japanese encephalitis in people.

Abundance of vectors is estimated in many different ways. A common method for mosquitoes is the New Jersey light trap. This trap has been used as a standard for estimating mosquito abundance for many years. In recent years, traps that use carbon dioxide

TABLE 1-1. Criteria for incriminating arthropods as vectors of human diseases (after Barnett, 1956).

1. Demonstration that the suspected arthropods feed upon human hosts of the pathogen, or otherwise make effective contact with human hosts under natural conditions.

2. Demonstration of a convincing biological association in time and space of the suspected arthropods and the occurrence of human disease cases.

3. Repeated demonstration that the suspected arthropods, collected under natural conditions, harbor the identifiable infective stage of the pathogen.

4. Demonstration of transmission of the identifiable pathogen by the suspected arthropods under controlled experimental conditions.

as an attractant, such as the CDC miniature light trap or the EVS (for encephalitis virus surveillance) trap, have been used for this purpose. However, the New Jersey light trap is still used widely because of the many years of data that are available for comparison.

Host Preference and Host-Feeding Patterns

Whether or not various species of insects actually "prefer" certain hosts over others is a subject which has been debated for a long time. Questions of this kind have most often been investigated using some kind of choice test in a laboratory, usually using a device known as an olfactometer. In nature, the matter of host preference is complicated by the relative availability of different species of hosts. Patterns of host feeding that are determined by identification of blood meals in vectors are usually the end result of many factors, including host preference and host availability. This is why the term "host preference" has given way to "host-feeding pattern" in vector biology literature. Host-feeding patterns are directly related to Barnett's first criterion for vector incrimination, and are important factors in the degree of vector-host contact. Host-feeding patterns usually are estimated by sampling vectors that have taken a recent blood meal, and then identifying the blood, usually by an immunological method, such as the precipitin test. Recently, more sensitive (but more tedious and expensive) tests, such as the enzyme-linked immunosorbent assay (ELISA), complement fixation, and gel immunoelectrophoresis have come into use.

It is difficult to obtain large numbers of blood-fed vectors for identification of blood meals. Within a given vector population, only some fraction of the individuals will be seeking blood meals at any given time. Collections of vectors made with traps using attractants, such as dry ice, tend to attract blood-seeking individuals, not those that have already fed. The most effective traps for collection of blood-engorged vectors are those designed for the collection of resting vectors (e.g., resting boxes or vacuum aspirators for mosquitoes). They are not biased toward any particular type of blood meal source or vectors in any particular physiological state, and result in relatively high proportions of blood-fed individuals.

Reproductive Capacity

Vector species vary considerably in their reproductive capacity, an important determinant of vectorial capacity. Reproductive capacity is a measure

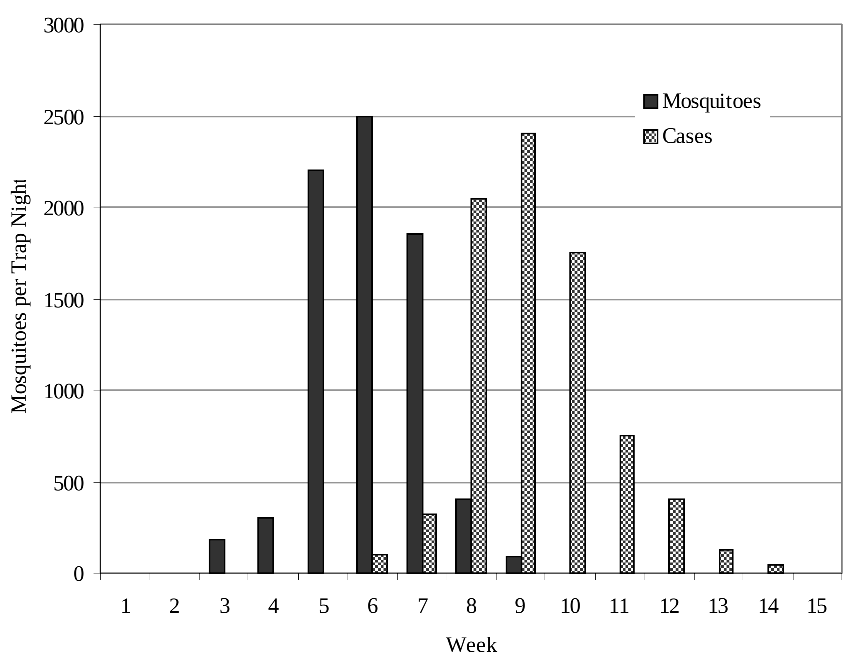

Figure 1-3. Population curves for *Culex tritaeniorhynchus* mosquitoes and human cases of Japanese encephalitis in the 1950 Tokyo epidemic (Barnett, 1956).

of the rate at which a population of vectors increases. Fecundity is a related term which relates to the number of generations, broods, or litters produced per unit of time. The net reproductive rate of a population of vectors is a combination of fecundity and survival. Survival is influenced by various mortality factors, including predation and diseases, as well as accidents and natural aging. These factors can be analyzed in life tables, which are tabulations of vital statistics of mortality and life expectancy for various age classes in a population. Life tables are useful for knowing which life stages are most vulnerable to various mortality factors. This information may provide insight into the design of control strategies, especially those involving biological control.

Longevity

Knowing how long a generation of vectors lives is almost as important as knowing their abundance. Longevity is most important for the life cycle stage that serves as a vector. Usually, a bloodsucking vector must take at least two blood meals in order to transmit a pathogen to a vertebrate host. The first blood meal is needed to acquire the pathogen from an infected host and a subsequent meal for transmission of the pathogen to an uninfected host. Vertical transmission of pathogens from parent to offspring (transovarial transmission), or from one life stage to another (transstadial transmission) may result in transmission at the time of the first blood meal. Generally, the greater the longevity of a vector population, the greater its vectorial capacity because the chance of vector-host contact is greater in long-lived vectors.

Longevity in vector populations can be estimated in one of two ways. The simplest and most direct method is to take some vectors of the same age and place them in a cage. The cage is checked every day and dead individuals are removed and recorded. This method usually results in overestimates of longevity because many mortality factors that occur in nature, such as predation and infection, are not present. An alternative approach (usually used with flying insects) is the field method known as mark-release-recapture. To estimate longevity, a large sample of vectors, either reared in the laboratory or captured in nature, is marked in some way (e.g., with fluorescent dusts of various colors), and released into the environment. Traps are then operated at various locations around the release point for a period of days or weeks. All of the trapped insects are examined under ultraviolet illumination and the number of marked individuals recorded daily. The number of recaptured vectors that are marked over time can be seen in the bar graph (Fig. 1-4). Daily survival can then be estimated using common statistical methods.

There are a number of less quantitative field methods that can be used to estimate longevity. One group of methods is called age-grading. Some of these methods are quite straightforward and simple, such as examining the amount of wear on wings of flying insects, or counting the number of parasitic mites present on the bodies of adult mosquitoes (the number of mites present tends to decrease with age). Other methods are more tedious and require dissections of female specimens and their examination under high magnification with a microscope.

Dispersal

The distance a vector can travel may influence its vectorial capacity. Flying insects have especially high potential for movement. Vectors that can move freely and for long distances will have greater chances for contact with humans, and will be more likely to move between infected and noninfected hosts. The term flight range is used to describe the farthest distance flying insects will travel from one place to another. Flying insects occasionally have been reported as flying many miles, but many of these reports are probably examples of the movement of insects in strong wind currents, and are not really representative of flight ranges.

Flight range for a given group of flying vectors usually is estimated using the mark-release-recapture method described above. The procedures used are very much the same as those used to estimate daily survival, except that traps for recapture are placed radially from the point of release. The distance recaptured insects travel then is recorded directly by the distance the traps are located from the release point. As with any behavioral observations, average response is more important than maximum response, and thus the distance traveled by 50 percent of the recaptured population is more important than the maximum distance traveled by any one individual.

Laboratory flight mills also are used to estimate flight ranges. Flight mills consist of a lightweight metal arm which rotates around a central pivot. To estimate flight range, insects are fixed (usually glued) to the end of the arm, and the number of revolutions of the arm is recorded under various experimental conditions. This is a very artificial system, and although distances flown on flight mills probably have some relationship to flight potential in nature, the exact relationship is unknown.

Vector Competence

Vector competence is defined as the susceptibility of a group of arthropods to a given strain of pathogen and the ability of those arthropods to transmit the pathogen. These traits are under genetic control, and although infection and transmission in vectors will vary with temperature, vector competence is considered to be an innate characteristic for a particular vector for a given microorganism. Vector competence is one of the most important factors comprising vectorial capacity. If a given species of arthropod is not competent to transmit a given pathogen, then that arthropod cannot be considered a vector. Its vectorial capacity would be zero because its vector competence is zero.

There are many reasons why some arthropods have higher vector competence than others. It has been shown that for mosquitoes and arboviruses, there are differences in the susceptibility of various mosquito tissues for infection. These differences are called barriers to infection. If a virus present in the body of an arthropod will not infect the salivary glands, the arthropod is said to have a salivary gland barrier for that virus. In other instances, specific tissues may become infected, but the virus particles cannot disseminate from those tissues. This situation is called an escape barrier. If, for example, a virus does not move from infected salivary glands into the salivary duct of an arthropod, a salivary gland escape barrier would exist.

Estimates of vector competence are made in essentially two ways: first, by recovery and identification of pathogens from samples of arthropods captured in nature; and second, from laboratory infection and transmission experiments. Estimating the vector competence of mosquitoes for viruses serves as an example. Using the first method, mosquitoes are trapped alive, sorted, identified, sexed, counted, and assembled into pools (typically of 50 each), and sent to a laboratory where viral assays are done. There, the pools are ground up and injected into experimental animals or tissue culture tubes. If virus is present, the experimental animals become sick, or in the case of the tissue cultures, visible plaques

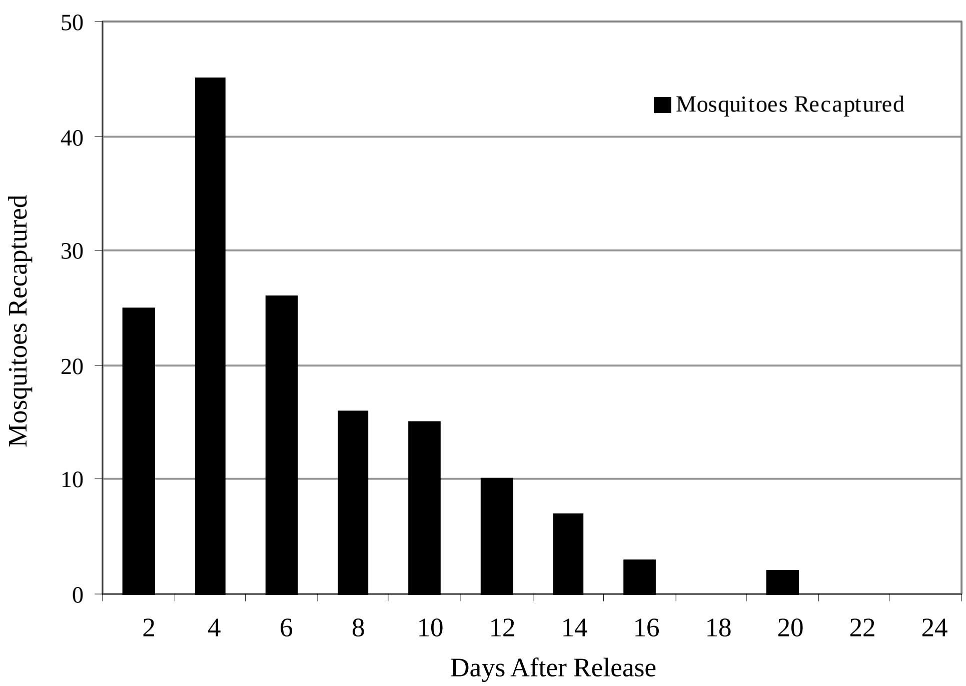

Figure 1-4. Bar chart of mark-release-recapture data used to estimate daily survival.

appear. Various immunological procedures are used to identify any positive pools, such as the hemagglutination-inhibition test or the cross-neutralization test. The proportion of positive pools usually is reported as a minimum infection ratio (MIR) of infected to uninfected individual vectors. The MIR often is expressed as the number of infected arthropods per 1,000 individuals tested.

Laboratory transmission experiments traditionally have been done with laboratory animals (mice, guinea pigs, etc.). Animals are infected with a known dose of some pathogen, and then held long enough for the pathogen to multiply and appear in the blood stream. Then a group of uninfected ("clean") potential vectors are allowed to feed on the infected hosts and held long enough for them to become infected and to be able to transmit the pathogens. After a suitable incubation period (known as the extrinsic incubation period), the test arthropods are permitted to feed on uninfected laboratory animals. These animals are then held for an incubation period (known as the intrinsic incubation period) and tested for evidence of infection, either by watching for signs of disease, or by testing their blood for the pathogens or antibodies against the pathogens.

Modern laboratory testing for vector competence sometimes substitutes artificial hosts for laboratory animals. Although not as natural, the use of artificial hosts avoids problems with the purchase, care, and feeding of laboratory animals. The use of live animals is now discouraged in most laboratories where there are satisfactory alternatives. Those alternatives include the use of artificial feeding systems using membranes or capillary tubes for infection of the arthropods, and the use of cell culture systems for detection and identification of the pathogens. Artificial systems have the additional advantages of producing more repeatable results and being less expensive.

HOST AND PATHOGEN FACTORS

Most discussions of vector-borne disease ecology stress factors that are related to vectors. However, the patterns of vector-borne disease that one sees in nature are strongly influenced by physiological and behavioral attributes of vertebrate hosts and pathogens. From the standpoint of disease ecology, the three factors of vector, host, and pathogen are inseparable, and all contribute to the epidemiology of vector-borne diseases.

The susceptibility of hosts to infection, the appearance of pathogens in the host's bloodstream after infection, and the ratio of asymptomatic to symptomatic infections in humans are all important determinants of patterns of disease. The susceptibility of nonhuman hosts is also important. This is because nonhuman hosts may play an important role in the amplification of pathogens, and thus their availability to human disease vectors. This is especially important where pathogens have seasonal cycles, and fall to low levels during some part of the year.

Virulence of pathogens and the host tissue attacked are also important in respect to particular hosts. Certain viruses tend to infect the nervous system of vertebrate hosts (e.g., western equine encephalomyelitis virus), whereas, others tend to infect visceral tissue (e.g., certain leishmanial parasites and yellow fever virus). This may have an affect on the seriousness of the disease in the vertebrate hosts, and also may determine the role the vertebrate host plays in the ecology of the disease. If infections do not result in the appearance of pathogens in the bloodstream, then the pathogens will not be available to bloodsucking arthropods, and the host will be a dead-end host.

LANDSCAPE EPIDEMIOLOGY
(Figure 1-5)

General

Biogeography is the study of the geographical distribution of plants and animals. The geographic distribution of vector-borne diseases is determined primarily by the geographic distribution of vertebrate hosts, disease pathogens, and arthropod vectors. In recent years, the study of biogeography applied to vector-borne disease distribution has been coined "landscape epidemiology." The large geographical areas of the earth (called biomes) are defined by climatic factors, especially temperature and precipi-tation. Within biomes, there are numerous smaller regions whose characteristics are determined by soil-related and other local factors, such as slope or proximity to bodies of water, or human activities, such as urbanization or agriculture. Many vector-borne diseases are closely associated with certain landscapes. One example is the present association of Lyme disease with forested areas inhabited by deer,

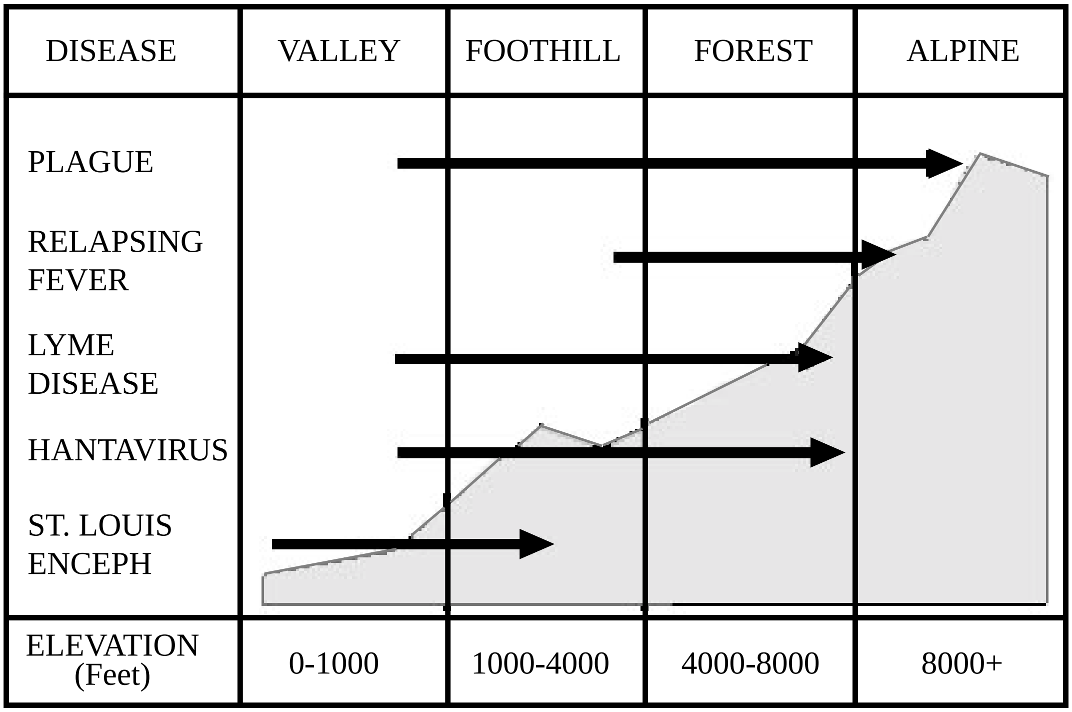

Figure 1-5. Landscape epidemiology and vector-borne disease.

especially where housing developments are close by. Some of the important aspects of landscape biogeography are discussed below.

Weather and Climate

The geographical distribution of plants and animals on the earth is primarily determined by patterns of weather and climate. Climates are classified on the basis of temperature and precipitation patterns. The most serious vector-borne diseases are associated with climates known as the wet tropics. Dry climates can be associated with vector-borne diseases under certain circumstances as well. California is unusual in that a number of climatic types occur within its borders, which is why the flora and fauna are so varied in this state, and why the potential number of vector-borne diseases is greater than elsewhere in the United States. The dominant climate in California is known as Mediterranean, or dry summer subtropical. Coastal marine and desert climates are represented as well.

Weather is important because of the strong influence temperature and rainfall can have on vector abundance and on the rate of development of pathogens within vectors. This is why outbreaks of certain diseases, such as St. Louis encephalitis, are generally associated with patterns of unusually high rainfall and unusually high spring temperatures.

Vegetation

Plants are considered to be the best indicators of climatic conditions. In ecology, patterns of vegetation are known as climatic associations. There are many classification schemes for vegetation. One excellent system is the Holdridge classification of vegetation. It is based on temperature and precipitation data for a given region and predicts the dominant type of vegetation that will occur in each region on the best available sites, i.e., where there exists the best soil conditions, exposure to the sun, drainage, and lack of disturbance. An example of a vector-borne disease that is probably influenced by vegetation patterns is La Crosse encephalitis, a serious mosquito-borne viral disease in the upper Midwestern United States. The primary vector, *Aedes triseriatus*, breeds in rot holes in deciduous trees. There may be a relationship between the emergence of La Crosse encephalitis and the reversion of farm land to forest in that area of the country.

Human Culture and Behavior

Human activities have a direct affect on vector-borne diseases. Generally, vector-borne diseases are rarely serious problems when natural environments are relatively undisturbed. This is especially true even in tropical rain forests, where many epidemics have occurred in formerly forested areas after land has been converted to agricultural or urban use. However, the reverse situation may have occurred in eastern North America, where the reversion of agricultural land to secondary forests and the construction of housing developments in forested areas may have been a contributing factor in the increase of diseases, such as Lyme disease and La Crosse encephalitis.

Assessment and Prediction of Disease Risk

There are three fundamental reasons for studying the epidemiology of vector-borne diseases: (1) to predict the occurrence of outbreaks; (2) to prevent occurrence of outbreaks; and (3) to abate outbreaks after an outbreak has occurred. Prediction of disease outbreaks usually involves comprehensive disease surveillance programs.

For malaria, surveillance consists primarily of the strict reporting of human cases, both imported and indigenous (locally-transmitted), followed by entomological investigations when indigenous cases occur. Surveillance for mosquito-borne viral diseases usually is done by testing for the presence of specific antibodies in blood samples drawn periodically from confined (e.g., sentinel chicken flocks) or wild birds and testing of mosquito samples for the presence of virus. In the last few years in California, very few confirmed cases of mosquito-borne encephalitis have been reported. This may have resulted because few human serum samples needed to confirm cases have been submitted by physicians to public health laboratories for testing, or there may be simply fewer human cases.

Plague surveillance in California is accomplished by sampling of rodents that serve as enzootic hosts and by human case detection. Large carnivores are also sampled because of the presence of plague antibodies in carnivore blood in endemic areas.

The basic principle of surveillance systems is to provide advanced warning of the probability of outbreaks of vector-borne diseases so that increased control procedures can be initiated. Different surveillance indicators vary in the amount of advanced warning provided. For mosquito-borne diseases, weather data, such as abnormally heavy snow pack, may provide several months of advance warning.

Abnormally high or low early spring temperatures may also be a factor in outbreaks. For viral diseases, the isolation of virus from mosquito pools usually will precede seroconversions in chicken flocks, although seroconversions in wild birds may be detected even earlier. When sentinel chicken seroconversions occur, the likelihood of a human disease outbreak increases. It is good to remember that indicators, such as sentinel chicken conversions, are the best predictors of human outbreaks, but provide little advance warning. Whereas, indicators, such as abnormally heavy snow pack, have less predictive value but provide the most advance warning.

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CHAPTER 2

FUNDAMENTALS OF ENTOMOLOGY

Richard P. Meyer[1]

INTRODUCTION

When one considers the multitude of animal life on earth, most thoughts are of fishes, reptiles, birds, and mammals. Insects and other arthropods, such as spiders, scorpions, and ticks invariably are overlooked in their overall contribution to the abundance and diversity of existing life forms. This is not surprising because insects are perceived as being comparatively small and inconspicuous living in a realm often referred to as the "Hidden World." For such an obscure life form, insects have significantly impacted the health and welfare of the human species since the beginning of recorded history. The economic losses wrought by these animals are staggering as a consequence of their destructive exploitation of agricultural produce, forestry products, and architecture.

Human health is similarly affected by certain insects (e.g., mosquitoes) that are known carriers of a variety of human diseases. The World Health Organization (WHO) estimates that at least three million humans, primarily children, die each year from mosquito-transmitted malaria infections acquired in Asia and Africa. Among other important diseases that affect humans worldwide and carried by insect vectors are plague, typhus, filariasis, yellow and dengue fever, and leishmaniasis.

The number of insect species in existence worldwide may exceed three million. This projection is based upon studies being conducted in tropical environments where entomologists are just beginning to reveal the immense complexity and diversity of insect life associated with tropical rain forests. Eventually, more than 70 percent of all known insect species may be found inhabiting the rain forests of Central and South America. The current estimate of the number of insect species found in North America is in the range of about 90,000 with new species being continuously added from ongoing taxonomic and genetic studies.

The global quantity or "biomass" of insects occupies at least 40 to 50 percent of the total volume of all animal life. This volume is produced by an astronomical number of individual insects estimated to approximate the number 10 followed by 15 zeros (10,000,000,000,000,000). Just an acre of grassland or rain forest may support millions of ants, termites, aphids, and beetles both above and below the ground in association with existing soil and vegetation types. This numerical superiority also extends to the limit of the land at both the North and South Poles where insects, and perhaps mites, predominate as the principal forms of terrestrial animal life.

Fossil insects from the geologic record go back 350 million years to the Devonian Period (Age of Fishes) with the appearance of *Rhynielia praecursor* (springtail) and *Eopterum devonicum*. From that time forward, insects have undergone significant adaptive changes in form to assure their survival and success in exploiting the earth's environmental resources. Insect adaptability still remains an unprecedented biological phenomenon that is unrivaled by any other life form, including the human species. Most entomologists attribute the biological success of insects to their: 1) diverse form, 2) anatomy and physiology, 2) reproductive potential, 3) developmental and feeding strategies, 4) dispersiveness, and 5) inherent capacity to adapt to changes in the environment.

The vector control technician should be familiar with the attributes of insects and other closely related animals that have enhanced their ability to survive and utilize existing resources. This chapter presents fundamental concepts of entomology with emphasis on the biology and classification of insects.

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WHAT IS AN INSECT?

Insects are highly specialized invertebrates in having an impervious exoskeleton composed of chitin, internally attached muscles, and segmented body movable only at the joints. This generalized body form is the distinguishing characteristic of an arthropod or "jointed foot" animal. The anatomical organization of insects is relatively simplistic in comparison to the more complex organization and specialization exhibited by advanced life forms. Principal physiological systems are arranged in a "logical" or functional sequence consistent with the front to rear (anterior to posterior) segmentation (Fig. 2-1).

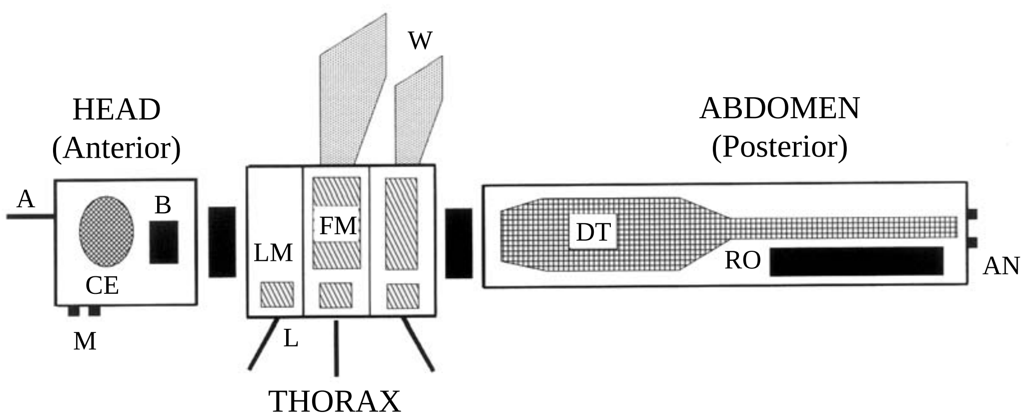
The body of an insect is uniquely differentiated into three distinct regions; the head, thorax, and abdomen. The head supports the majority of the central nervous system (brain), primary sensory structures (compound eyes and antennae), and mouthparts. The thorax bears the organs of locomotion (1-2 pairs of wings or none, and 3 pairs of legs). Relatively unspecialized, the abdomen contains the bulk of the digestive tract (alimentary canal), reproductive organs (ovaries and testes), and supports a variety of specialized structures related to mating (e.g., male claspers) and egg laying (e.g., female ovipositor).

INSECT ANATOMY AND BIOLOGY

External Anatomy (Figure 2-2)

Exoskeleton: The exterior of an insect is covered by an impervious shield of interconnecting plates and segments that form the exoskeleton. The chemical composition of the exoskeleton includes a variety of different substances with chitin as the principal component. Chitin (chemically: nitrogenous polysaccharide) is extremely durable, impervious to water loss and absorption, and textured in a manner to aid survival. Individual plates of chitin form sclerites that are close fitting and connected either along immovable sutures or membranous joints. The exoskeleton must be strong and capable of supporting the internal musculature and associated stresses created by muscular contractions.

The exoskeleton is composed of four distinct layers based upon chemical and cellular composition. The outer waxy layer in direct contact with the environment is the epicuticle. This layer minimizes water loss and absorption from within and outside of the body, respectively. Beneath the epicuticle is the thicker exocuticle composed largely of hardened (sclerotized) chitin, which provides the bulk of the structural support and strength to the exoskeleton. Underlying the



Legend: A=antenna, B=brain, CE=compound eye, M=mouth, FM=flight muscle, W=wing, LM=leg muscle, L=leg, DT=digestive tract, RO=reproductive organs, AN=anus.

Figure 2-1. Functional organization of an insect.

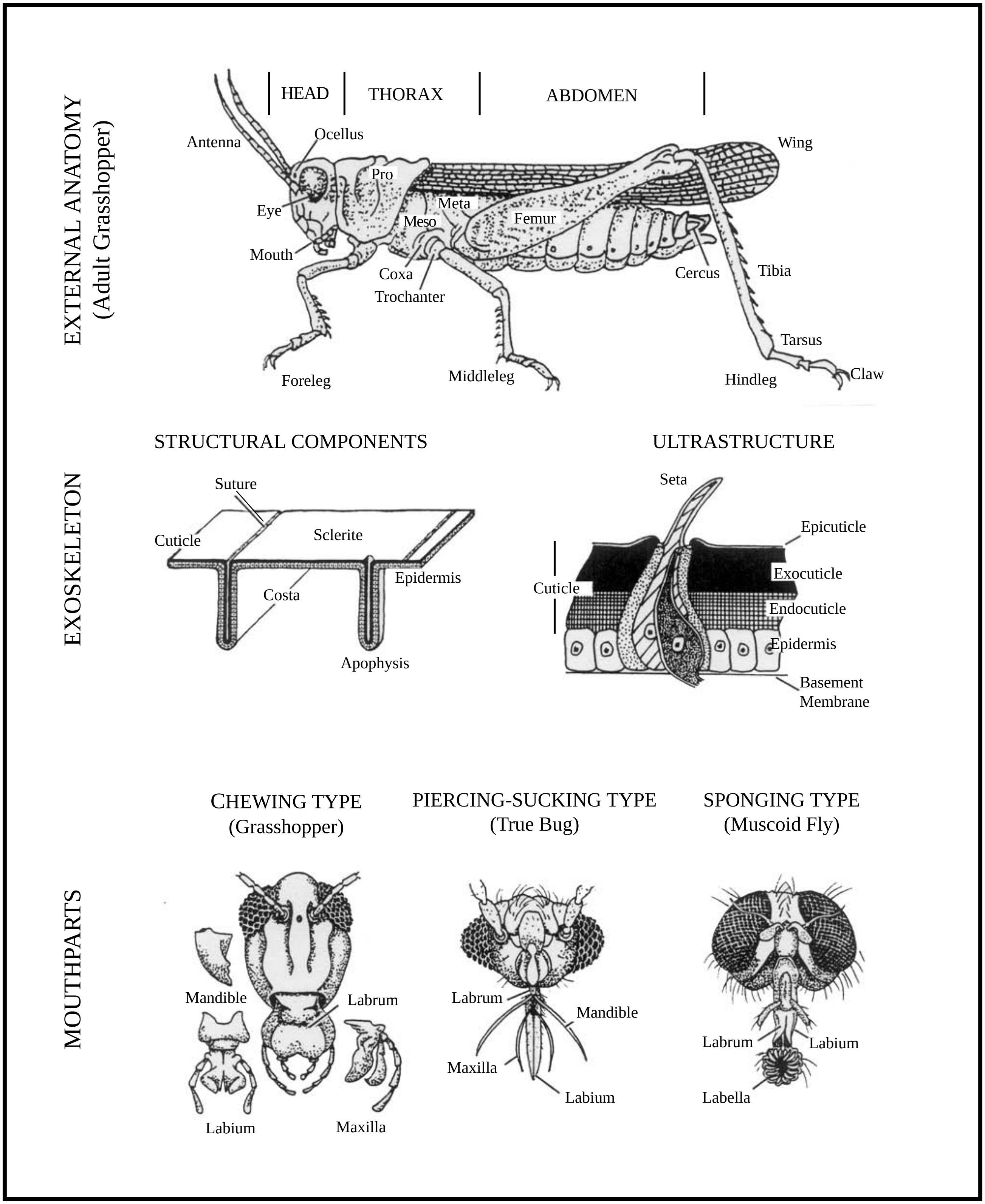


Figure 2-2. Insect anatomy and mouthparts.

exocuticle is the softer and more pliable endocuticle. Together, the epicuticle, exocuticle, and endocuticle form the cuticle. The fourth layer below the cuticle is the epidermis, which consists of a thick layer of cuboidal cells and thin basement membrane. Various accessory structures are associated with the cuticle, including scales, setae, spines, sculptured processes, and specialized dermal glands.

Body Regions and Associated Appendages

Head: The head of an insect is composed of a number of sclerites that encapsulate and protect the brain and give support to the principal sensory and feeding structures. Logically, the head or anterior (front) end is the part of the insect that first encounters the environment when it moves about or feeds. Therefore, all structures adaptive to that phenomenon are associated with sensing environmental conditions and feeding. Among the important sensory structures found on the head are the paired antennae and compound eyes. The mouth and its associated structures are located either at the base or extreme front end of the head capsule. The head is attached to the thorax at the neck by a sclerotized ring or cervix, which is designed differently among insects to accommodate variable movements.

Thorax: The thorax is the middle region of the insect body that supports the walking legs and wings, and the musculature associated with each of these locomotion mechanisms. The thorax is further subdivided into three segments with the prothorax (first segment) usually separate from the fused mesothorax and metathorax (middle and hind segments). One pair of walking legs is attached to each segment and named accordingly; fore, middle, and hindlegs. Each leg is composed of five segments that are named similarly to the anatomical components of mammalian extremities. Beginning at the base of the leg at the attachment point with the thorax, the first segment is the coxa followed by a short trochanter, longer femur and tibia, and terminal tarsus. The tarsus is comprised of up to five smaller segments or tarsomeres with the terminal tarsomere (pretarsus) bearing either a single or double claw. The wings, if present, are attached to the meso (e.g., flies) and/or metathorax (e.g., termites). The pair of wings attached to the mesothorax are considered the forewings and those attached to the metathorax, the hindwings.

Abdomen: The abdomen is the rear (posterior) most region of the insect body that contains the principal portion of the digestive tract, reproductive system, and excretory organs. The abdomen is subdivided into 11 (I-XI) segments that exhibit a high degree of specialization among different insect orders and families. Differences in the form of the abdomen relate to life history and reproductive strategy. The specialized terminal segments (segments IX-XI or terminalia) are highly modified for mating and egg laying. Male terminalia are characterized by the presence of claspers and females by the ovipositor. The terminal abdominal segment may bear a single pair of cerci.

Sensory Organs

Vision: Insects do not see with their "eyes" in the same manner as vertebrates, which have the capacity of forming a stereoscopic (single) image from the retinas of two adjoining eyes. Instead, their vision may be considered as bizarre because the field of view is not integrated into a single image, but presumed to be integrated from a composite of mosaic views perceived by an array of individual simple eyes or facets. Facets are arranged in a variety of radial symmetries to form the large compound eyes that provide a near global field of view. The number of facets comprising the compound eye can vary greatly between different insect species. For instance, the compound eyes of an adult dragonfly can have upwards of 50,000 individual facets, while lice or thrips may have compound eyes with fewer than 10 facets. In addition to the compound eyes, some insects have ocelli (accessory simple eyes) that are specialized for monitoring subtle changes in light levels that accompany the transition from day to night and vice versa.

Taste, Smell, and Pheromones: Taste and smell are detected by special nerve receptors called sensilla that are uniquely sensitive (chemoreceptors) to detecting the presence of chemical substances associated with these senses. Chemoreceptors commonly are found clustered on the antennae, mouthparts, and tarsi. Additional sites may include specialized areas on the wings, thorax, and abdomen. The antennae usually are involved with the detection of pheromones, which are chemical substances produced by insects as an additional mechanism of communication and mate detection. Pheromones in some social insects (e.g., termites, ants, and bees) also function to maintain social order in the colony and retard the primary sexual development of the worker castes.

Sound: Insects sense sound in a variety of different ways by detecting either the airborne or ground vibrations (sound wave energy) generated by the source. Sound waves or vibrations usually are detected overall by the body, or more specifically by specialized sensillae located on the antennae and tarsi. Extremes in sound detection are found in certain groups of nocturnal moths that use specialized tympanal organs at the base the abdomen to receive the echolocation signals of insectivorous bats. The ability to detect the presence of a bat by its echolocation signals provides a moth with a mechanism to avoid being eaten by taking any number of evasive maneuvers.

Mouthparts

No other single group of organisms exhibits the diversity of "structure and function" as do the insects with their impressive array of specially adapted mouthparts. There are species and groups of insects that have mouthparts designed for either chewing, piercing, rasping, sucking, or sponging. The greatest diversity in mouthparts is found among the sawflies, bees, and wasps with mouthparts that are adapted to chewing vegetation and obtaining nectar from flowers. Another group of insects, the flies, also exhibit a high degree of mouthpart specialization with species that either pierce prey or suck blood with piercing mouthparts, lap plant exudates and predigested food with unique sponging type mouthparts, or slash and lap blood with a combination arrangement of slashing, lapping, and sucking structures.

Chewing Mouthparts: Chewing or mandibulate mouthparts represent the most common occurrence in structure among the insects. The anterior to posterior arrangement of the various structures associated with this type of mouthparts can be subdivided into four separate functional units beginning with the upper lip or labrum-epipharnyx, followed by the paired mandibles, paired maxillae, and lower lip or labium-hypopharnyx. Chewing mouthparts are used to tear and macerate food items before they are ingested. Common insect groups with chewing mouthparts include grasshoppers, roaches, lacewings, beetles, and wasps. Presented at the bottom of Figure 2-2, are three types of mouthpart arrangements exhibited by a majority of insect species.

Piercing and Sucking Mouthparts: Piercing and sucking mouthparts are highly modified (tubelike) to extract either plant juices, the predigested tissues of prey, or blood. The labrum is generally reduced in size (sometimes a short flap below the clypeus) with the mandible and maxillae forming the piercing "stylets," which enter either plant or animal tissues to ingest nutrients. The labium forms an outer protective sheath that encloses the mandibles and maxillae and does not enter the puncture. In addition, the labium acts as a guide to support the entry of the stylets into the site of the puncture. The mouthparts of mosquitoes are more highly modified with the labrum-epipharnyx, in conjunction with the hypopharnyx, forming the food canal and salivary duct, respectively. Examples of insects with piercing and sucking mouthparts include the mosquitoes, conenose bugs, and fleas.

Sponging and Lapping Mouthparts: The arrangement and adaptation of mouthparts are found in flies that feed by predigesting their food and lapping up the processed nutrients by a specialized structure (labium), which functions like a sponge and channel to convey food to the pharynx.

Siphoning Mouthparts (not illustrated): This mouthpart arrangement is typical of the butterflies and moths that sip nectar, plant exudates, and moisture from different sources. The coiled proboscis consists of two opposing and interconnecting tubes (galea of the maxilla) with the food canal formed between the inner surfaces of the joined galea. Uncoiling of the proboscis occurs when the galea are "pressurized" with haemolymph (insect blood).

Internal Anatomy (Figure 2-3)

Nervous System: The nervous system of an insect is composed of the brain, subordinate nerve centers or ganglia, and an interconnecting network of nerve cells or neurons. The arrangement of the brain and ganglia (central nervous system) complements the segmental nature of the insect structure. Located in the head along with auxiliary ganglia, the brain coordinates most body functions related to the senses, growth, and development. Behind the brain and continuing through the thorax

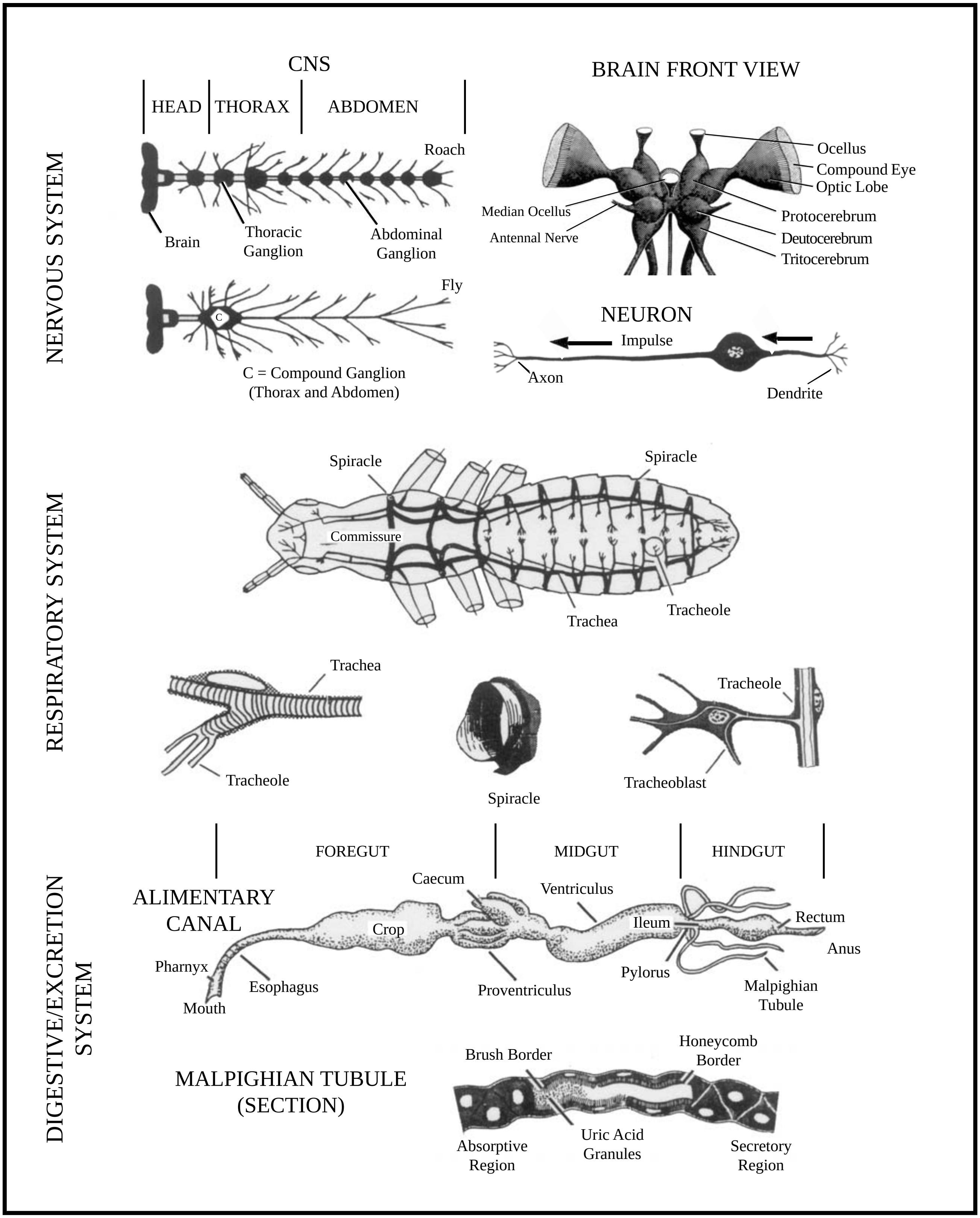


Figure 2-3. Insect internal anatomy and physiology (Figure modified from Chapman, *The Insects, Structure and Function*, 1971).

to the end of the abdomen are additional ganglia in each segment connected in series by the ventral nerve cord. Ganglia coordinate muscular movements within each segment and between segments. This arrangement also facilitates rapid and precise coordination between sensory and muscular (motor) nerve networks. Nerve cells or neurons transmit impulses in the form of electrical energy that travels the long axis of the cell. Individual neurons are connected at joints called synapses where the impulse is transmitted chemically from one neuron to the next. The enlarged end of the nerve cell, which receives an impulse, is called the dendrite while the long slender portion, the axon, transmits the impulse to the adjoining neuron.

Respiratory System: Metabolism and muscular movements of insects require the uptake and distribution of oxygen to all body tissues. Insects do not have lungs or other analogous structures that transfer atmospheric oxygen to the blood (haemolymph) for distribution throughout the body. Instead, insects have a specialized system of bifurcating tubes and tubules composed of trachea and tracheoles, which deliver oxygen directly to tissue cells where oxygen diffuses from the fluid contained within terminal microscopic tracheoblasts (Fig. 2-3). Air enters into the tracheal system through specialized openings in the exoskeleton called spiracles. The arrangement of spiracles varies among the different groups of insects. Spiracles usually are found on the sides of the thorax and along the abdomen where oxygen demand is highest for muscular, digestive, and reproductive activity. The entire system is ventilated by rhythmical and/or coordinated muscular contractions within the thorax and abdomen.

Circulatory System: The circulation of haemolymph (blood) in insects does not occur in a closed system of arteries, veins, and capillaries where blood is forced through these vessels by a complex heart. Insect circulation occurs in an “open system” that bathes the internal organs with free-flowing haemolymph. The only vessel consists of a dorsal aorta, which rhythmically pumps pooled haemolymph from the abdomen towards the head and thorax. Additional haemolymph circulation is provided by muscular contractions when the insect is either active or ventilating air in and out of the tracheal system. The haemolymph of insects does not transport sufficient oxygen to the body tissues (tracheal system performs this function) but does carry nutrients, electrolytes, and hormones to target tissues.

Digestive System: The digestive system of insects is highly specialized to accommodate the variety of insect diets associated with herbivorous, predatory, and parasitic species. Regardless of diet, the organization of the major structures comprising the digestive system is shared in common among most insects. The alimentary canal (gut) of a “generalized” insect runs the entire length of the body with the beginning portion comprising the foregut, the midgut (middle section), and hindgut (rear section). Beginning at the mouth, minced food mixed with saliva enters the foregut at the pharynx and travels down the esophagus to either the crop or proventriculus where digestive processes begin. From there, the partially processed food enters the midgut (mesenteron) to be further digested into its various nutritional components that are absorbed into the body. Roughage and unabsorbed nutrients remaining in the midgut pass through the pylorus into the hindgut where additional nutrients are absorbed by the intestine (ileum) and water by the rectum. The remaining bolus present in the rectum is compressed into a solid mass and passed through the anus as fecal material in the form of a pellet.

Excretory System: The generalized excretory system of most insects consists of specialized sausage-shaped structures called malpighian tubules (analogous to vertebrate kidneys) that are attached to the alimentary canal at the pyloric junction between the mid and hindgut. Each tubule is comprised of large quadrate cells that are specialized to either remove or concentrate metabolic waste products (e.g., uric acid or urea) extracted from the haemolymph. As a waste product, urea is a crystalline nitrogenous substance that is both nontoxic and insoluble in water. Additional functions of the malpighian tubules include maintaining the proper balance of water and various electrolytes (salts) in the haemolymph.

Endocrine System: The endocrine system of insects consists of neurosecretory cells and endocrine glands, which are stimulated by the central nervous system to produce specific chemical substances (hormones) that either maintain or regulate major physiological functions. Excited by nerve signals from the brain, neurosecretory cells produce chemicals that travel down nerve tracts to any number of endocrine glands that are stimulated to produce site specific hormones. Among the more important endocrine glands are the corpora cardiaca, corpora allata, and prothoracic glands. Hormones secreted by the corpora cardiaca regulate heart rate while the corpora allata produces juvenile hormone (JH) to regulate growth and metamorphosis in conjunction with the prothoracic glands governing molting via production of the molting hormone ecdysone.

Reproductive System: The reproductive systems of male and female insects are typical of most arthropods that mate (sexual reproduction) to produce offspring from fertilized eggs. Eggs of female insects are produced by either one or two ovaries located in the hind portion of the abdomen. Egg development proceeds as nutrients ingested by the female are converted into yolk that is deposited in each egg surrounding the oocyte (unfertilized ova). When a developing egg receives sufficient yolk, the chorion (egg shell) is secreted to cover the entire surface of a mature egg. The egg is now ready for deposition and fertilization. Sperm enter an unfertilized egg through the micropile (a microscopic pore) at the base of the egg. The micropile soon closes after either a single or multiple sperm have entered the egg where only one sperm unites with the oocyte to complete the fertilization process. The oviposition (deposition) of eggs is guided by an ovipositor. The structure and function of the ovipositor (e.g., stinger in bees and wasps) is extremely variable among insects and related to their life history strategy as either a predator, parasite, or herbivore.

The male insect reproductive system is relatively simple with the sperm being produced by one or two testes located in the rear of the abdomen. When a male and female mate, sperm is transferred from the testes down the sperm ducts and out through the adeagus (intromittent organ), which is inserted into the female's genital opening. Male insects often possess claspers (specialized structures) at the tip of the abdomen for grasping and coupling with the female of the same species. The nature of the claspers is unique to each species and forms a "lock and key" linkage/bond between the sexes.

GROWTH AND METAMORPHOSIS

Growth: Insects do not grow in the normal sense of gradually increasing their size and in the process slowly developing wings, legs, and other adult morphological characters. This growth phenomenon typical of vertebrates is not possible with insects because their exoskeleton (cuticle) does not expand to accommodate growth, but remains rigid with only minimal plasticity. Insects must, therefore, periodically shed their old cuticle and produce a new cuticle that expands and eventually hardens shortly after molting. The process of shedding the old cuticle is called molting. When a moth caterpillar or grasshopper nymph is ready to molt, they cease feeding and empty the contents of the gut. Simultaneously, the prothoracic glands begin producing ecdysone, which initiates the absorption of the old cuticle (endocuticle), secretion of the new cuticle, and shedding of the surface layer (exocuticle-molt skin) of the old exoskeleton.

Metamorphosis: The number of times an insect immature molts prior to transforming into the adult stage varies among different insect groups and is largely dictated by life history strategy. However, there is a common pattern to this process that can be applied to most insect species. Insects are either produced as live young or hatch from eggs deposited by the female sex. Once free from the egg or female body, the immature must undergo a structured process of growth and development to reach maturity. This process is known as "metamorphosis" (meta = change and morph = form). As an example to illustrate how metamorphosis occurs, lets begin with an ordinary grasshopper that has just hatched from an egg deposited in the soil. The young nymph begins feeding on grasses and expands slightly to a point where the cuticle must be shed for the young hopper to grow. The old cuticle is shed, the nymph increases its size, begins feeding, gains weight, and again reaches a point where the old cuticle must be shed in order for it to grow. This process is repeated a number of times until the mature nymph finally gives rise to a young adult when it molts for the last time.

The number of times an insect nymph or larva molts usually is set for a given species. Most immature insects molt from four to eight times, however, the nymphs (naiads) of some dragonfly and mayfly species undergo as many 12 to 28 molts, respectively. The stage of the immature insect between molts is called an "instar" with the first instar occurring between egg hatch and the first molt, the second instar between the first and second molts, the third instar between the third and fourth molt and so forth. The last molt produces either the adult or pupa depending upon the developmental strategy involved with metamorphosis. Production of juvenile hormone by the prothoracic glands ceases sometime during the last instar, which switches the transformation process from forming a new instar to forming the adult.

Developmental Strategy (Figure 2-4)

No Metamorphosis (Ametabolous): This type of metamorphosis occurs in primitive insects that do not show any degree of differentiation from young immatures to mature adults. Examples of insects with no metamorphosis include springtails, silverfish, and bristletails.

Simple Metamorphosis (Paurometabolous and Hemimetabolous): Insects with simple metamorphosis develop from nymphs (pauro) or naiads (hemiaquatic nymphal stage of mayflies, dragonflies, damselflies, and stone flies) that resemble a wingless form of the adult stage. Among some of the insects with simple metamorphosis are the roaches, grasshoppers, aphids, cicadas, plant bugs, thrips, and lice.

Complete Metamorphosis (Holometabolous): This is the most advanced form of metamorphosis among insects where a species develops from an egg, larva (note: the number of larval molts and instars varies greatly among different groups and species), and pupa before transforming into an adult. The pupa represents a unique transitional stage between the larva and adult where many external features of the larva are converted into the typical appendages and wings associated with the adult form. A vast majority of the insects in existence today exhibit complete metamorphosis; among which are the lacewings, beetles, butterflies, moths, flies, wasps, and bees.

INSECT CLASSIFICATION AND DIVERSITY

Species Concept and Nomenclature

The diversity of animal and plant life on earth is comprised of a myriad of different organisms exhibiting many unique and common attributes that can be used

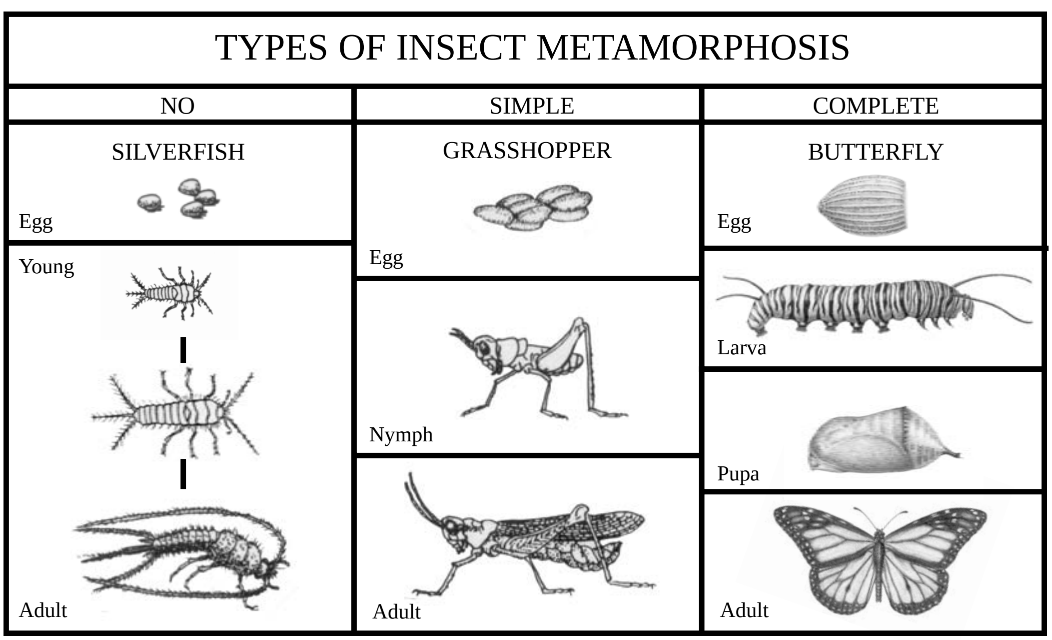


Figure 2-4. Types of insect metamorphosis.

to arrange them into common groupings based upon shared morphological and genetic characteristics. This system can be further subdivided to a level where an organism can be discriminated by its unique set of characteristics that are shared by other "identical" individuals occupying common space and exchanging compatible genetic material in the course of mating and producing viable offspring of the next generation. This level delineates a "biological species." Every species known to science is given a proper scientific name to avoid confusing references attributed to species by the use of vernacular and colloquial common names.

The Swedish naturalist Carl Linnaeus developed the system of scientifically naming species by incorporating a Latin binomial (scientific name presented in italics or underlined) with the first nomen (word) identifying the genus (first letter capitalized) and the second nomen (word) identifying the species (lower case). According to scientific custom, the first time a species is presented in literature its binomial is written in full followed by the last name of the taxonomist who first described it as a species. The human species is identified by the binomial *Homo sapiens* Linnaeus, the domestic dog by *Canis familiaris* Linnaeus, and the house fly by *Musca domestica* Linnaeus. Among widespread species splintered into distinct local populations that are morphologically or genetically separable from other local populations, a subspecies designation is frequently applied to produce a trinomial (3 words). For example, the honey bee, *Apis mellifera* Linnaeus, has many races or subspecies throughout Africa and Europe. One such unique race is the African honey bee, *Apis mellifera scutellata,* of equatorial east Africa. The name "*scutellata*" identifies this race of the honey bee as the African subspecies.

Higher Categories of Insect Classification

The Linnean system of nomenclature is complemented by a hierarchy of classification that systematically subdivides either plant or animal life into various groups/categories that have common (diagnostic) characteristics of form and organization. Life on earth is usually viewed as being either plant or animal. The life forms comprising the viruses and other closely related forms are not considered as being either plant or animal; but a unique kingdom, the protists. Among the animals are organisms that run the spectrum of size and complexity ranging from simple one-celled organisms (Protozoa) to humans. Insects are classified as animals belonging to the kingdom Animalia from where they are further categorized in the phylum Arthropoda ("jointed foot" animals). The phylum Arthropoda is further subdivided into classes (e.g., Arachnida = spiders and Chilopoda = centipedes) that are separated by their unique segmented body form and specialized appendages. Insects are placed in the class Hexapoda (= Insecta) by the nature of "six-footed" arrangement of the three pairs of legs attached to the thoracic segments.

Since insects exhibit considerable diversity in structure and form, this class has been separated into a number of orders largely on the basis of wing venation, mouthparts, and metamorphosis. For example, the dragonflies and damselflies belong to the order Odonata (tooth-wing), the beetles to the order Coleoptera (shield-wing), and the butterflies and moths to the order Lepidoptera (scale-wing). Each of these orders is easily distinguished from the others by the characteristic appearance of its species; dragonflies versus beetles versus butterflies. Orders also are divided into a number of more discriminating categories that include suborders, superfamilies, families, subfamilies, and tribes. The hierarchy of classification ultimately descends to the level of the genus and species at a "position" below the level of the subfamily and/or tribe. As an example for illustrating the current scheme of plant and animal classification, lets examine the taxonomic status (classification) of the common housefly, *Musca domestica* Linnaeus.

KINGDOM- Animalia,
  PHYLUM- Arthropoda,
    CLASS- Insecta / Hexapoda,
      ORDER- Diptera,
        FAMILY- Muscidae,
          GENUS- *Musca,*
            SPECIES- *domestica,*
              AUTHOR (described by) Linnaeus

Insect Diversity (Figure 2-5, Table 2-1)

The classification of insects has undergone significant changes in recent history with major revisions involving the higher categories. Many of the changes were recognized with recent discoveries in

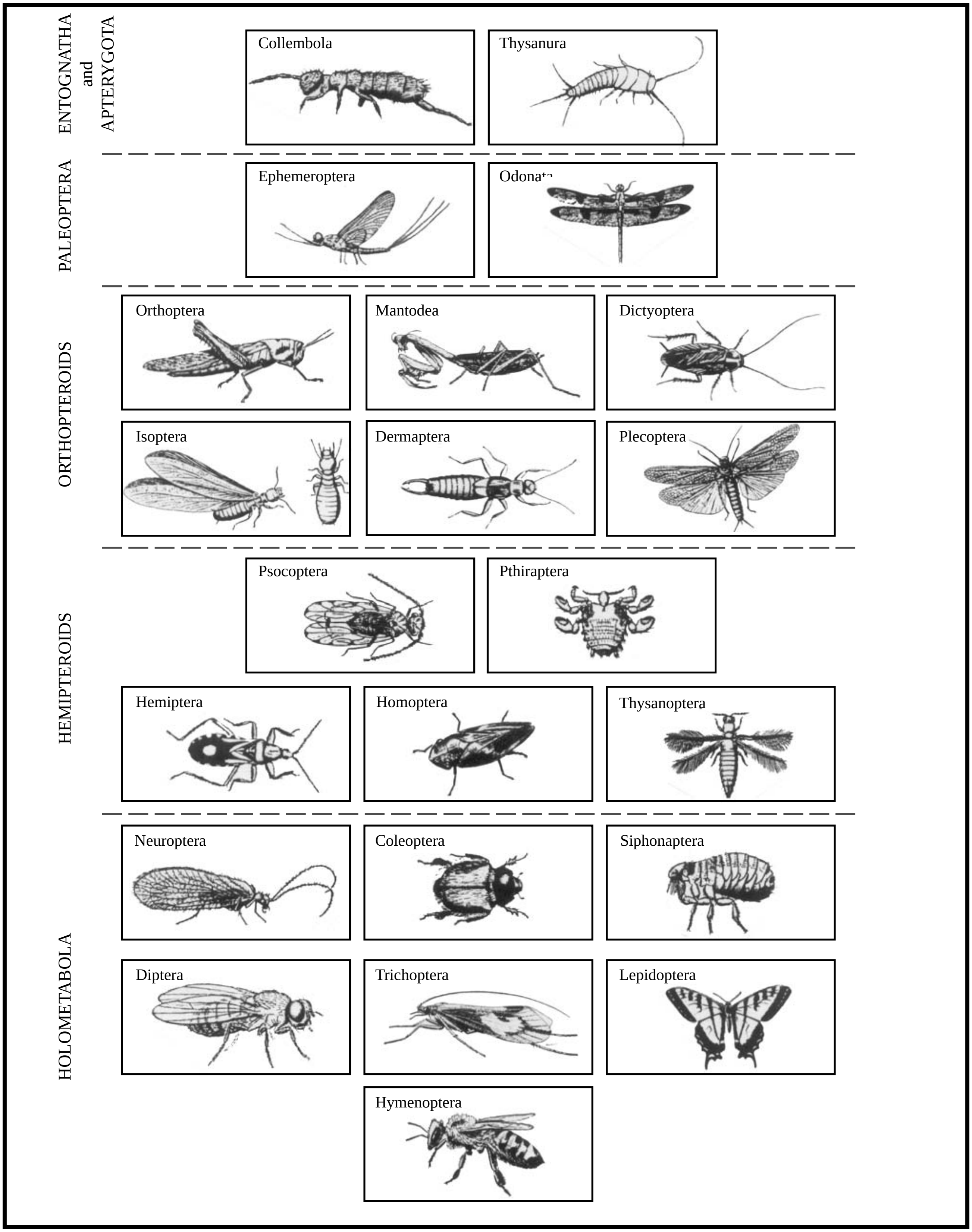


Figure 2-5. Common insects orders.

TABLE 2-1. Diagnostic characteristics of the common insect orders.

NO METAMORPHOSIS

COLLEMBOLA: Antennae and abdomen with six or fewer segments, forked appendage (“furcula”) at the end of the abdomen, mouthparts concealed by head capsule

THYSANURA: Body covered with metallic scales, end of abdomen with three filaments, mouthparts adapted for chewing.

SIMPLE METAMORPHOSIS

EPHEMEROPTERA: Forewings large with complex network of veins and held vertically above thorax, end of abdomen with two or three long caudal filaments, mouthparts adapted for chewing. Nymphs are aquatic.

ORTHOPTERA: Forewings (tegmina) held roof-like, hind-legs specialized for jumping, mouthparts adapted for chewing.

DICTYOPTERA: Body flattened, head concealed from above, wings (if present) held flat, mouthparts adapted for chewing.

DERMAPTERA: Body slightly flattened, wings folded beneath a pair of shortened tegmina, end of abdomen with a pair of anal forceps, mouthparts modified for chewing.

PSOCOPTERA: Two pairs of membranous wings, fore pair larger than hind pair and held roof-like, mouthparts adapted for chewing.

HEMIPTERA: Body elongate to oval with the hemielytra (forewings) part membranous and held flat, mouthparts adapted for piercing and sucking.

ODONATA: Fore (front) and hindwings similar with a complex, network of veins, compound eyes prominent, antennae bristle-like, mouthparts adapted for chewing. Nymphs are aquatic.

MANTODEA: Prothorax elongate and bearing raptorial forelegs, wings held flat, mouthparts adapted for chewing.

ISOPTERA: Social insects with wingless soldier and worker castes, two pairs of wings alike and held flat, mouthparts adapted for chewing.

PLECOPTERA: Two pairs of membranous wings, flap on hindwing, end of abdomen with elongated cerci, mouthparts adapted for chewing. Nymphs are aquatic.

PTHIRAPTERA: Wingless ectoparasites (1-10 mm) with body flattened, mouthparts adapted for chewing (suborder Amblycera = chewing lice) or piercing-sucking (suborder Anoplura = sucking lice).

HOMOPTERA: Wings (if present) membranous with fore pair larger than hind pair and held roof-like, mouthparts adapted for piercing-sucking.

THYSANOPTERA: Minute insects (1-2 mm) with the body slightly flattened, wings narrow with “feather-like” fringes and held flat, mouthparts adapted for rasping and sucking.

COMPLETE METAMORPHOSIS

NEUROPTERA: Body elongate, membranous fore and hindwings similar and held roof-like, mouthparts adapted for chewing.

SIPHONAPTERA: Wingless ectoparasites (1-2 mm) with body compressed laterally, legs specialized for jumping, mouthparts adapted for piercing and sucking.

TRICHOPTERA: Mothlike insects with two pairs of wings (fore pair larger) held roof-like, wing veins with fine hairs and occasionally scales, mouthparts adapted for chewing. Larvae are aquatic.

COLEOPTERA: Fore (front) pair of wings (elytra) armored and covering the membranous, hind pair used for flight, mouthparts adapted for chewing.

DIPTERA: Single pair of wings attached to the mesothorax with the hind pair (if present) modified for coordinating flight, mouthparts highly diversified.

LEPIDOPTERA: Two pairs of wings with scales covering areas between the veins, mouthparts adapted for sipping.

HYMENOPTERA: Two pairs of membranous wings (hind pair reduced) held flat, mouthparts adapted for chewing and lapping. Females of most species possess stingers.

the fossil record coupled with a better understanding of the morphological interrelationships among present-day insects. There still exists unresolved controversial aspects of the origin and phylogeny (evolution) of the insects from their primitive ancestral forms. The following synopsis of the classification of the insect orders has been adopted from the classification scheme currently recognized by most entomologists. The orders are listed phylogenetically beginning with the evolutionarily most primitive insects and concluding with those that are evolutionarily most advanced.

CLASSIFICATION OF THE INSECT ORDERS

ENTOGNATHA (mouthparts enveloped by head capsule).

Order: Protura (protrurans)
Order: Collembola (springtails)
Order: Diplura (diplurans)

INSECTA (mouthparts exposed and not enveloped by head capsule) Apterygota (wingless forms in the adult stage).

Order: Microcoryphia (bristletails)
Order: Thysanura (silverfish)

PTERYGOTA (winged or secondarily wingless forms in the adult stage).

PALEOPTERA (wings not folded at attachment to thorax).

Order: Ephemeroptera (mayflies)
Order: Odonata (damselflies and dragonflies)

NEOPTERA (wings folded at attachment to thorax).

ORTHOPTEROIDS

Order: Grilloblataria (rock crawlers)
Order: Phasmida (walkingsticks and timemas)
Order: Orthoptera (grasshoppers and crickets)
Order: Mantodea (mantids)
Order: Dictyoptera (cockroaches)
Order: Isoptera (termites)
Order: Dermaptera (earwigs)
Order: Embiidina (webspinners)
Order: Plecoptera (stone flies)
Order: Zoraptera (zorapterans)

HEMIPTEROIDS

Order: Psocoptera (book lice)
Order: Pthiraptera (lice)
Order: Hemiptera (true bugs)
Order: Homoptera (cicadas, aphids, etc.)
Order: Thysanoptera (thrips)

HOLOMETABOLA

Order: Neuroptera (dobsonflies, lacewings, etc.)
Order: Coleoptera (beetles)
Order: Streptsiptera (twisted-wing parasites)
Order: Mecoptera (scorpionflies)
Order: Siphonaptera (fleas)
Order: Diptera (flies)
Order: Trichoptera (caddisflies)
Order: Lepidoptera (butterflies and moths)
Order: Hymenoptera (sawflies, wasps, ants, and bees)

PRESERVATION OF INSECT SPECIMENS

Insects and other arthropods submitted by the public to vector control agencies usually are identified to the lowest possible taxonomic category (order, family, genus, etc.). Once a specimen is received and identified, it provides a vector control agency with voucher specimens that can be used to corroborate the identification of specimens received in the future when a determination becomes tentative. If a specimen cannot be identified with a high degree of certainty, then it should be examined by an expert or experienced taxonomist.

The preservation of insects and arthropods requires some degree of finesse associated with established methodologies for either pinning, pointing, preparing microslide mounts, or using preservatives (e.g., ethyl alcohol) for voucher specimens (Fig. 2-6). A number of entomological texts can be referenced for details concerning recommended procedures for using insect pins, paper wedges (points), and various types of fluid preservatives. Regardless of the method of preservation, every specimen must be labeled appropriately with information that includes the location, date, and collector. The location data should include the nearest town or popular site illustrated on Auto Club and/or topographic maps, the county, and state. The style of entering the date of collection varies between entomological institutions. The University of California presents the date of collection using the format that notes the month in Roman

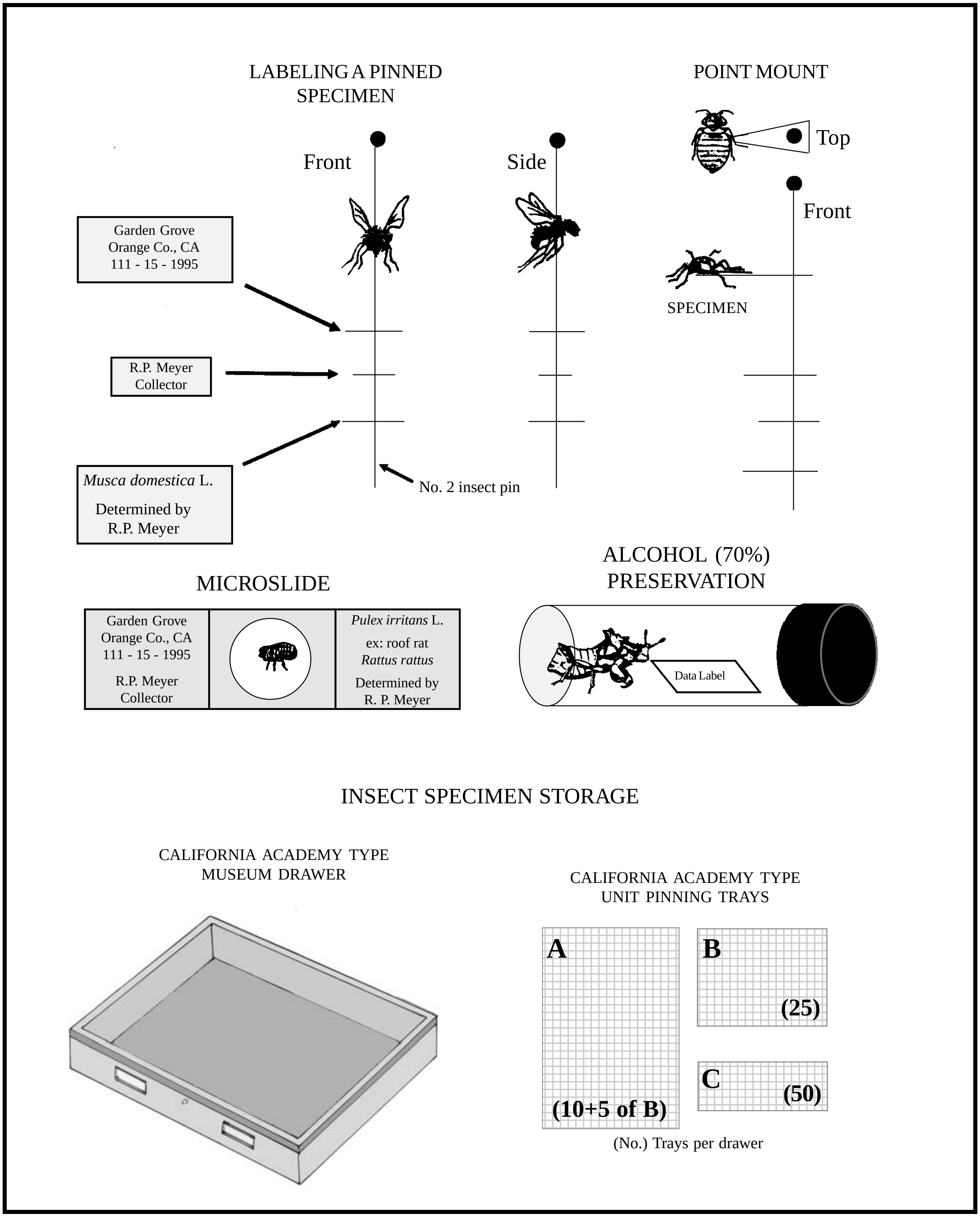


Figure 2-6. Methods of preserving and storing insects for taxonomic reference.

Numerals followed by the day and the year in Arabic. For example, a specimen collected on March 15, 1995 would have the date entered on the location/date label according to the following format: III-15-1995. Specimens frequently are identified by an additional determination label that gives either the scientific name or lowest taxonomic category determined by the collector or expert. Illustrated in Figure 2-6 are examples of how insect specimens are mounted and appropriately labeled.

Once insect specimens have been properly preserved, labeled, and identified they must be assembled in a collection for future reference and study. Established entomological museums house their collections in glass-topped museum drawers placed inside protective storage cabinets. Individual drawers are either lined with composition bottoms for inserting insect pins or masonite to support unit pinning trays. Most drawers are manufactured with label insets on the front panel for identifying the contents as to order, family, genus, or species. Currently, registered fumigants are placed inside individual drawers to protect specimens from damaging museum pests, such as dermestids or "carpet beetles." Specimens preserved in alcohol can be stored in drawers specially designed to support various types and sizes of museum vials with tight sealing screw caps. Microslides are kept in either vertical slide boxes or custom horizontal slide trays.

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Notes

CHAPTER 3

COCKROACHES

Donald A. Reierson[1]

INTRODUCTION

Of the nearly 3,500 described species of cockroaches worldwide, only a few are of public health concern. In the United States only two species live and breed exclusively indoors, while three others infrequently invade and reside in structures. Of all cockroaches, the German cockroach, *Blattella germanica* (L.), is by far the most widespread pest species, having been implicated as a mechanical vector of a wide range of pathogenic microorganisms. Domestic (domiciliary) cockroaches often live in close association with bacteria, fungi, and viruses, and should be considered significant potential public health pests when they invade or become established indoors. Some innocuous endemic cockroaches become incidental intruders as they fly to room lights or crawl under doors or around screens, especially on warm summer evenings. These cockroaches are of no public health significance.

DESCRIPTION AND BIONOMICS

Cockroaches are paurometabolous, in that they undergo gradual metamorphosis. Adult cockroaches have wings, immatures do not. Cockroaches do not have a larval or pupal stage, the immature stages essentially having the same general body shape as adults. It is important to note that immature and adult cockroaches have essentially identical food and shelter requirements. Cockroaches have an elongate oval shape and are somewhat flattened in appearance. Most are uniformly brownish or black. They have long slender segmented antennae and well-developed eyes. The antennae may be longer than their body. Their head lies nearly concealed beneath a flat, round shield-like structure called a pronotum. Cockroaches have long slender legs characterized by flattened coxae and heavily spined tibae. Adults of all domestic species have two pair of thin, translucent wings or wing buds that lie flat on their back. Immature cockroaches are called nymphs. Nymphs have the same basic shape as adults but do not have wings. Depending upon the species, female cockroaches lay ten to thirty eggs that develop inside a protective capsule they secrete called an ootheca. No other insects except mantids produce oothecae. Eggs develop into embryos inside the protective ootheca (egg capsule), and after developing within the ootheca for weeks or months, the embryos emerge simultaneously as nymphs.

Of subtropical origin, pest species of cockroaches have adapted to living indoors where their pest status derives from their close association with humans. They are found worldwide. Cockroaches can develop anywhere there is moderate temperature and humidity and adequate food and water. They may proliferate under conditions maintained in most buildings. The term domiciliary or "domestic" refers to their living in structures. While some species have adapted to the urban condition to such an extent that they live only indoors, virtually never being found outdoors, other species are invasive, generally being found elsewhere but sometimes invading and developing indoors. Obligatory indoor species usually develop in occupied places where large quantities of food are prepared or stored, especially in substandard multi-unit housing, commercial kitchens, homes, hotels, hospitals, zoos, and prisons. Their presence is indicative of poor sanitation. Invasive species, on the other hand, are more reclusive, coming in contact with humans when they gain access to buildings from sewer system lines and manholes, subway tunnels, storm drains, or masonry meter boxes. Their presence is indicative of faulty and deteriorating construction. Although the greatest incidence of domiciliary cockroaches tends to be in crowded cities in regions of the world that have year-long moderate weather, domestic cockroaches are common worldwide. For example, domestic cockroaches have even been reported to infest

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buildings in areas as diverse as deserts in the Middle East and frozen outposts in Alaska and the Antarctic.

A significant adaptive feature of cockroaches is their behavioral and physiological plasticity. Cockroaches can a.) survive harsh conditions by adjusting to the situation, b.) readily endure stressful conditions, c.) survive extended periods of time without food or water, d.) adapt to a wide range of temperature, moisture and light regimens, and e.) tolerate high doses of noxious substances that would ordinarily kill many other insects. Although cockroaches prefer starchy foods when given a choice, under duress they will eat just about any substance, including leather, paper, fingernails and eyelashes, and even wood. Small crumbs and droplets of water can sustain large numbers of cockroaches for weeks.

Cockroaches prefer and seek dark places and they aggregate in groups in cracks, crevices, and other protected places, usually near food and water. They remain hidden during daylight hours. Cockroaches exhibit repetitive circadian patterns of activity whereby they are quiescent in light and become active during the dark. They normally avoid light, but will quickly become accustomed to illuminated areas if forced to do so. They readily adjust their behaviors to accommodate almost any regular light-dark cycle. For example, reversing the cycle of light and dark in a building quickly reverses the periods of activity and rest of cockroaches in the building.

Cockroaches tend to travel along junctions and edges rather than out in the open. This behavioral characteristic protects them from predators and provides them a quick exit into a protected place if they are either threatened or disturbed. Domestic cockroaches have few effective natural enemies. They are fed upon by rats and mice as well as lizards, geckos, and birds. Their tendency to aggregate and to leave oothecae incubating unattended for long periods of time suggests that cockroaches would be susceptible to control by introduced biological organisms. However, although several specialized groups of wasps (Encyrtidae, Eulophidae, Evaniidae, and others) are cockroach oothecal parasitoids, their overall effectiveness has generally been ineffectual, even when conditions are presumably optimal for the wasp.

Cockroaches mark their home territory with specialized chemicals called pheromones that are secreted in their feces. Other pheromones and secretions affect behavior in a variety of ways, including marking food and new surroundings, delimiting trails and pathways that they frequently travel, and for attracting the opposite sex for mating. Individual cockroaches will aggressively respond to food odors or water if they have been deprived of either for a long time, but they will not respond when satiated. This anomaly has important implications in terms of controlling cockroaches with food baits.

Although multiple matings occur, female cockroaches *may* mate only once. Sperm is held in a special internal structure (spermatheca) for months and is released as needed to fertilize mature eggs within the female. Females may produce several egg capsules in succession, each containing a complement of fertilized eggs. For this reason, large numbers of cockroaches may apparently develop suddenly from just a few fertilized females. Also, because it takes a long time for nymphs to develop to adulthood, this phenomenon of having multiple oothecae results in mature populations of cockroaches usually consisting of about 75% nymphs. Adult and nymphal cockroaches cannibalize molting nymphs if the population is starved or overcrowded, resulting in a higher percentage of adults and larger nymphs. This dynamic of food availability and cannibalism eventually broadens the territorial range of the population as some nymphs inevitably escape and disperse to less populated sites.

From young nymph through adulthood, the average life span of a cockroach ranges from about one to more than four years. Adults live about six months to two years. High temperature shortens both the time for development and adult longevity. Larger species tend to live longer and take longer to complete their life cycle. For instance, the Oriental cockroach, *B. orientalis*, requires up to two years to develop from egg to adult, whereas, the smaller German cockroach completes its life cycle within about four months. Overall, most species of cockroaches spend about half of their life in the nymphal stage.

LIFE CYCLE

The generalized life cycles for the species of domestic cockroaches are similar, the difference being the number of instars to adulthood and whether the ootheca (Fig. 3-1) is deposited versus remaining attached to the female while it develops.

Cockroaches mate within a few days of maturing from the last nymphal instar. Females deposit eggs internally into a segmented ootheca that develops gradually over a period of a few days. The ootheca protrudes from the rear end of the female, darkening and hardening as it is extruded. Except for the German cockroach, females either indiscriminately drop the ootheca once it is fully formed or glue it by means of oral secretions to a substrate where it incubates. For German cockroaches, however, the ootheca remains attached at the posterior end of female throughout the period of embryo development. Nymphs often emerge (eclose) from the egg capsule while it is attached to the female, the ootheca being subsequently discarded indiscriminately. Development of embryos in the ootheca may range from as little as six weeks for the smaller species to more than four months for the larger species.

Nymphs grow through a series of five to seven growth stages called instars, older nymphs being larger than younger ones. Nymphs are soft and whitish colored for a few hours when they emerge from the ootheca and after each molt into the next instar, each time forming a new skin (cuticle) and casting off their old. They are virtually defenseless at this time. Nymphs develop slowly, taking several weeks to more than a year to reach adulthood. Mature males and females that develop from the same capsule readily mate with one another.

PUBLIC HEALTH IMPORTANCE

The medical importance of cockroaches has been addressed by several researchers, but several recent authors including Ebeling (1975), Koehler et al. (1990), and Brenner (1995) have reported extensively that cockroaches have been implicated with number of medical maladies, including the transmission of several diseases that affect humans.

All domestic species of cockroaches have pest status by virtue of being an offensive nuisance, but some are associated with filth, transmission of disease, and with contact and inhalant allergies. Fortunately, most people do not come in direct contact with cockroaches on a regular basis. Cockroaches stain and foul foods and other

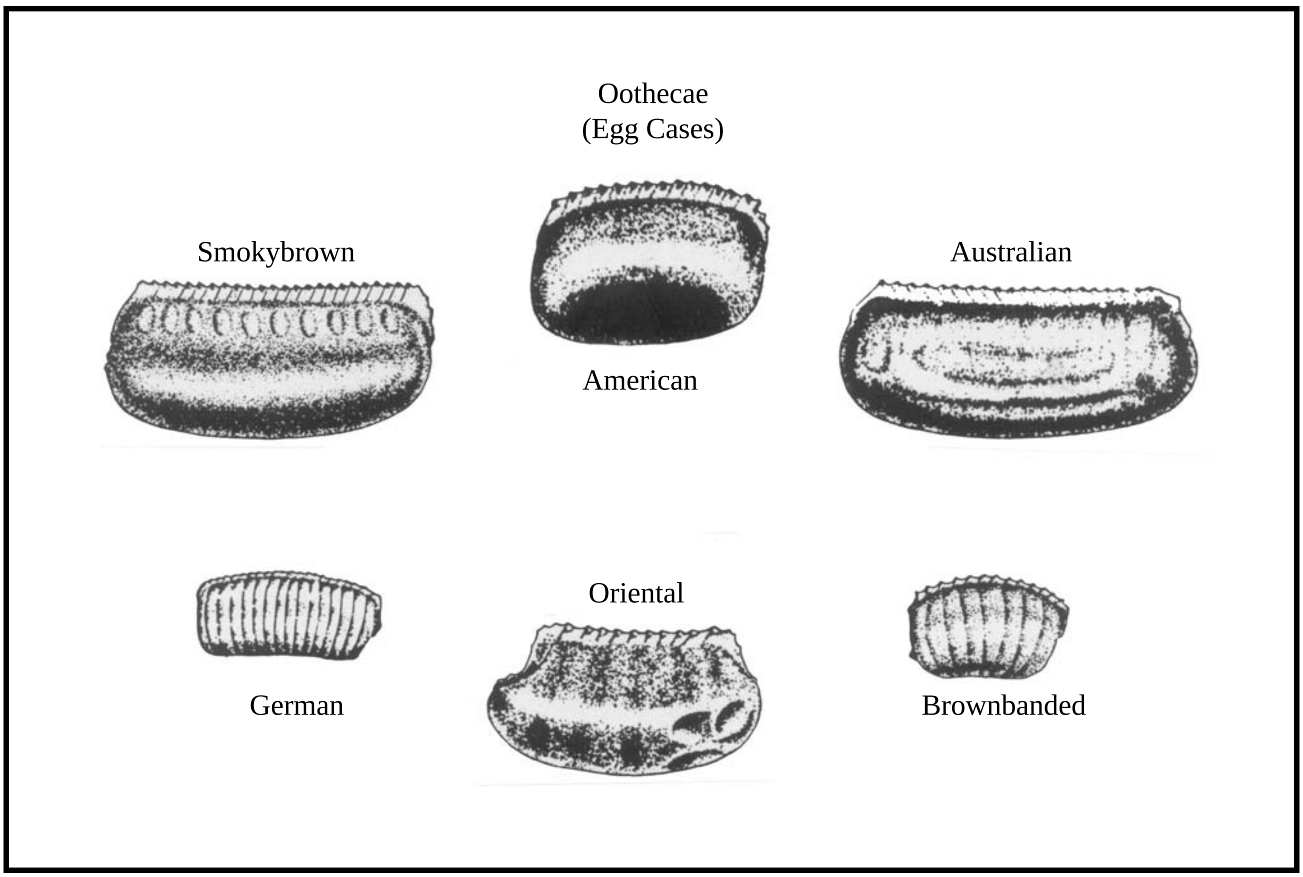

Figure 3-1. Cockroach egg cases (courtesy Pictorial Keys, CDC, 1966).

items with their saliva, excrement, and shed skin. They may introduce contaminants merely by crawling from a "dirty" surface to a clean one. Some people are so fearful of cockroaches that it affects their mental health. Fear of cockroaches usually is related to the size of the species and their numbers. Generally, the presence of even a few cockroaches indoors should be considered more than just a nuisance. Appropriate control action should be taken to eliminate any existing indoor infestation and to prevent further occurrence.

The presence of cockroaches is likely an indication of unsanitary conditions. Cockroaches have been implicated as carriers of microorganisms that cause dysentery, hepatitis, and other illnesses in hospitals and nursing homes. In extremely rare instances, cockroaches have been reported to crawl into ears or even bite people. This occurs only with enormous unchecked infestations, and usually when food-deprived cockroaches are eating food residues (such as dried milk) left on soft skin. More significant, however, are recent studies that indicate that cockroaches are responsible for thousands of cases of severe inhalant allergy among children who have a history of exposure to cockroaches at home or school. The allergic reaction is induced by exposure to fragmented cockroach cuticle. Studies also show that some people may have cross-reactive allergic reactions to other arthropods including shrimp, lobster, crayfish, and house dust mites, and that the severity of the reaction may be attributed to past exposure to cockroaches.

Several pathogenic microorganisms have been isolated from field-collected domestic cockroaches, and it is presumed that under certain conditions these microorganisms may be transmitted to humans. It should not be inferred that cockroaches regularly transmit these organisms to humans and cause disease. Rather, one should note that transmission of these organisms by cockroaches is apparently rare but that a close association between cockroaches and disease has been documented repeatedly.

An array of disease microorganisms have been isolated from field-collected cockroaches or recovered after inoculation of cockroaches in the laboratory. An incomplete list of the most important and widespread include helminths, such as pinworms and tapeworms; protozoans, such as *Entamoeba* and *Giardia* that cause dysentery; various fungi and molds; bacteria that cause dysentery, gastroenteritis, and food poisoning; and viruses.

There is limited definitive evidence that cockroaches contribute significantly directly to human disease, but their habits and proven association with pathogens warrants safe and effective efforts to eradicate or suppress cockroaches where we live, especially in restaurants, schools, hospitals, and convalescent homes. Special attention to cockroaches should be taken wherever food is prepared, served, or stored.

SPECIES ACCOUNTS
(Figure 3-2)

As far as is known, the German cockroach, *Blattella germanica* (L.), and the brown banded cockroach, *Supella longipalpa* (F.), are the only species of cockroach that live exclusively in man's structures. Three other species, the Oriental cockroach, *Blatta orientalis* L., the American cockroach, *Periplaneta americana* (L.), and the smokybrown cockroach, *Periplaneta fuliginosa* (Serville), occasionally invade and become established indoors, but are considered to be peridomestic in that they live primarily outdoors or in sewer systems and masonry enclosures.

German cockroach, *Blattella gemanica*.

The German cockroach is by far the most troublesome domestic species of cockroach in the United States. Adults are about 0.6 inches (1.5 mm) long, are tawny brown, and have two parallel dark streaks that course the length of their pronotum. Males are more slender than females, have a yellowish abdomen that gradually tapers to the posterior end. Nymphs are mostly dark, but their intersegmental membranes are tan colored. This gives nymphs the appearance of having a series of subtle stripes extending across their body. In addition, nymphs have a distinctive broad tan median longitudinal stripe that extends the length of their thorax. This stripe gives the appearance of a tan patch on their thoracic dorsum.

German cockroaches do not have a volatile sex pheromone as do the other domestic cockroaches. Rather, receptive females are attracted to a greasy nonvolatile sex pheromone secreted by males from special glands situated on their 7th and 8th tergites.

German cockroaches prefer dark, moist conditions near 29°C (84°F). Females mate soon after becoming adults, and produce their first ootheca within about eight days. Over their life span females produce about seven

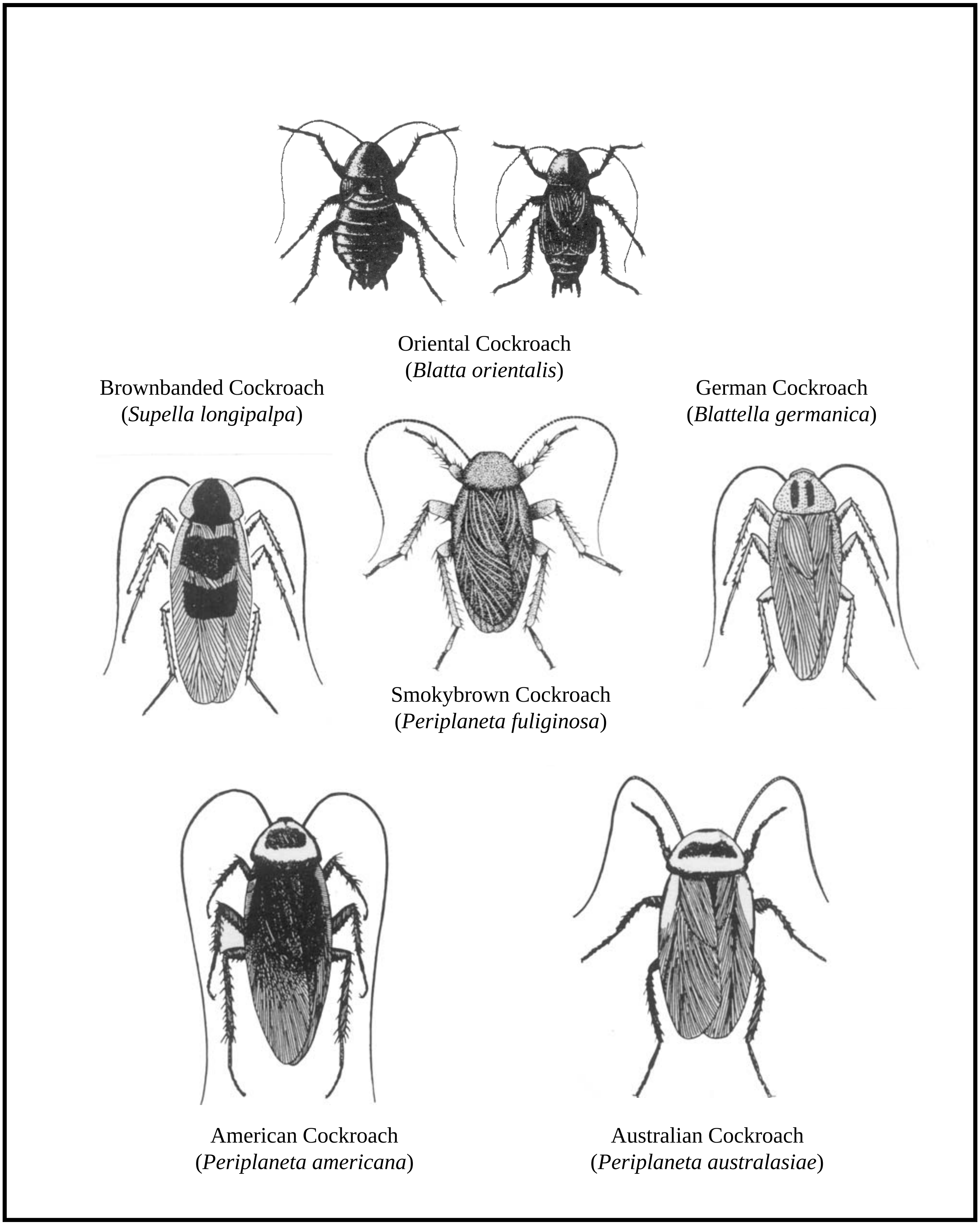

Figure 3-2. Adult cockroaches (courtesy Pictorial Keys, CDC, 1966).

oothecae, each containing about 25 to 35 young. A new ootheca is formed about every three to four weeks, depending on food and environmental conditions. As stated previously, nymphs often hatch from the ootheca while it is attached to the female. Interestingly, female nymphs develop much more rapidly in groups. The average nymphal developmental period for males is 39 days regardless of whether they are kept in isolation or in groups. Female nymphs, on the other hand, require 63 days in isolation, but only 41 days when in groups. Life span varies, but seems dependent on food and temperature. Experimentally, when kept at 30°C adult males lived an average of 128 days, and females lived 153 days. But at room temperature an individual German cockroach generally lives about 200 days, and may live as long as 10 months.

German cockroaches live exclusively indoors. A closely related species, the field cockroach, *B. vaga* Hebard, lives outdoors, and is sometimes confused with *B. germanica*.

Because of its high reproductive potential, its propensity to occupy remote and inaccessible locations within a building, and its ability to forage long distances, *B. germanica* often remain undetected until enormous populations develop. Even if some cockroaches are found, it is often difficult to determine the "source" or where the bulk of the population resides.

Brownbanded cockroach, *Supella longipalpa*.

A relatively recent introduction into the United States from Africa by way of Cuba and the West Indies, *S. longipalpa* was first found in Miami and Key West in 1903, but was not considered to be a household pest until about 1940. The optimal temperature for development of brownbanded cockroaches is above 26.7°C (80°F), and they tend to seek higher temperatures. This temperature preference differential usually separates populations of *S. longipalpa* and *B. germanica*, the latter preferring more moderate temperatures. Probably because they prefer warm areas, they tend to be found near the ceiling within a room, or in the upper rooms of multistory buildings.

Brownbanded cockroaches are similar in size and shape to *B. germanica*, the male being more slender than his German cockroach counterpart. Brownbanded cockroaches are colorful as far as cockroaches are concerned. The head and thorax of adults range from dark brown to black. The wings of females are reddish brown to dark brown, while those of the male are dark brown at the base, becoming lighter posteriorly. Under reflected light their wing venation and pattern gives adult *S. longipalpa* a shiny, glistening appearance. The lateral margins of the pronotum and lateral margins of the anterior portions of the wings are translucent. Both sexes have a pale brown band at the base of the wings and across the middle of their back, hence the brown banded appearance. Their ventral body surface and legs are pale yellowish. Adult *S. longipalpa* remain still when at rest as do *B. germanica*, but when disturbed they scurry in bursts of running and stopping rather than in continuous long runs.

Nymphal brownbanded cockroaches are even more striking than the adults. They are dark brown but have two nearly parallel narrow pale tan stripes across their thorax, with a broad pale brown area on the dorsum of the abdomen. The contrast of the pale tan and brownish with the darker areas gives the nymphs the appearance of being more "banded" than are the adults.

Brownbanded cockroach egg capsules are reddish brown, and are the smallest of the domestic cockroaches, measuring only 1/8 x 3/32 in. (4 x 2.5 mm). They are usually deposited in clusters on textured vertical surfaces. A prominent green band forms across the middle of fertile oothecae. Females produce up to 15 oothecae during their life span, each ootheca containing 14 nymphs that emerge after incubating for about 50 days at 27.8°C (82°F). The temperature sensitivity of this species is demonstrated by the fact that the incubation period of the ootheca doubles to 100 days at 22.2°C (72°F). Similarly, in one study nymphal development at 22.2°C took 161 days, but only 93 days at 29°C (83°F). Because buildings are not usually maintained at the high temperatures optimal for their development, the incidence of *S. longipalpa* is less than 5% than for *B. germanica*.

Oriental cockroach, *Blatta orientalis*.

Sometimes called "water bug" or "water beetle," *B. orientalis* is cosmopolitan and unique in that it prefers cool moist environments and cannot climb smooth vertical surfaces.

Adults are 1 to 1-1/4 in. (2.5 to 3 cm) long and shiny black. Females have rudimentary wing buds, and the males have wings that extend about 3/4 the length of their abdomen. The ootheca is dropped or fastened to a substrate. At first the ootheca is smooth and reddish brown, but it darkens and hardens as it incubates.

Oothecal incubation period lengthens with decreasing temperature, it being 42 days at 29.5°C (85°F), but 60 days at 22.2°C (72°F). An average of eight nymphs emerge from each capsule. Young nymphs are tiny (< 6 mm long) and whitish when they first hatch, soon becoming light brown. Nymphs become increasingly dark in subsequent instars, eventually looking very much like adults.

Oriental cockroaches take a long time to develop and development time is also temperature dependent. The reported period for nymphal development is 520 days at ordinary room temperature (22.2°C) (72°F), 295 days at 28°C (82°F), and as short as 164 days at 30°C (86°F).

Oriental cockroaches outdoors live under wood, stones, and pieces of concrete, in enclosed masonry structures, such as water meter boxes, and in ground cover plantings. They prefer dark places and are primarily nocturnal, gaining access to warehouses, garages, and other buildings when they randomly move from a damp crawl space or from nearby vegetative plantings. Oriental cockroaches cannot effectively regulate their body water. As a consequence, they leave their surroundings if their environment dries. They enter buildings through open doorways, unsealed floor joints, under sliding doors, and around utility pipes. Indoors *B. orientalis* usually reside in enclosed cool, damp places near water. Because Oriental cockroaches lack arolia (sticky cup-like structures) on their tarsi, they cannot climb smooth vertical surfaces. They are therefore often found trapped in jars, sinks, and bathtubs.

American cockroach, *Periplaneta americana*.

American cockroaches are large (about 4 cm long), reddish brown with a paler yellow area around their pronotum. Adults have long slender antennae, shiny, reddish-brown wings covering the abdomen, and a pair of well-developed long, slender, segmented cerci at the tip of the abdomen. Adult males also have a pair of styli between the cerci.

First-instar nymphs are grayish white. Subsequent instars are reddish brown, having a striped appearance because the posterior margin of each body segment is slightly darker. There are 9 to 13 instars, wing pads first appearing in the third or fourth instar. Nymphal developmental period depends on temperature, but averages about 12 months. The American cockroach is long lived. The adult life span of *P. americana* depends on temperature; adults at room temperature living an average of about 400 days. They have been reported to live as long as 1,293 days.

Females produce an average of nearly 60 ootheca, about one per week. About 8 by 15 mm and reddish brown when first dropped or deposited, the ootheca becomes black within a day or two. The ootheca desiccates easily and requires high humidity for hatching, and perhaps this is why it is found in large numbers only in damp locations. Although there is a wide range, depending on environmental conditions, on the average each ootheca contains about 13 nymphs that hatch after incubating about 40 days.

American cockroaches are somewhat reclusive, usually avoiding direct contact with humans. It is the most common domestic species infesting sewer systems. They also infest warehouses, steam tunnels, subway tunnels, and basements. They are rarely found in the living quarters of homes or apartments, but they sometimes infest secluded areas in commercial buildings.

Smokybrown cockroach, *Periplaneta fuliginosa*.

The smokybrown cockroach, a common peridomestic species in the southern states, has become established as far north as Illinois, and is well-established in several areas in California.

The smokybrown cockroach is shorter than the American cockroach. Adults are about 33 mm long, are mahogany dark brown to black, and have shiny wings that cover their abdomen. It is more slender and delicate looking than are the other members of its genera, and is the only uniformly dark species of *Periplaneta* in the United States. The ootheca has the same general appearance as for *Periplaneta americana* except that it is longer. Females usually glue their ootheca in a crack or crevice, and attempt to conceal it with bits of debris. The ootheca contains nearly 40 nymphs, which hatch after incubating about 40 to 70 days, depending upon temperature. Young *P. fuliginosa* nymphs can be distinguished from other species of cockroaches by the white tips on their antennae and a transverse white band that extends across their thorax. Interestingly, the period for nymphal development appears to be affected more by whether the nymphs develop in groups versus isolation rather than by temperature. The period for nymphal development ranges from about 200 to 450 days.

Smokybrown cockroaches are opportunistic foragers. They are most active at night, feeding on seeds, bird and pet droppings, pet food, and virtually any food left unattended. Although *P. fuliginosa* live primarily in trees outdoors, they also have been found under logs, stones, and wooden flower pots or similar protected sites. They will infest buildings if permitted to do so. Like *P. americana*, they have been found infesting sewer systems. Indoors, *P. fuliginosa* prefer warmer areas, often residing in attics.

Australian cockroach *Periplaneta australasiae*

The Australian cockroach (*Periplaneta australasiae*) was introduced into North America from the South Pacific via commerce with Pacific Rim trading partners. There have been scattered records for California where this species has been discovered in coastal environs near ports of entry. Where this species has become established, it seldom occurs outdoors, but more predictably indoors in close association with food storage and preparation areas. Currently, the Australian cockroach is commonly found in the southeastern United States and appears to be most abundant in Florida where it is locally referred to as one of the "Palmetto Bugs." This species is included herein because there always remains the possibility that *P. australasiae* may at some point in time be introduced in sufficient numbers to become more firmly established and widespread in California.

Adults of the Australian cockroach are on the average one inch (25 mm) long and easily recognized by their overall brown coloration, yellow pattern on the pronotum, and unique lateral yellow stripe that extend one-third down the outer margin of each of the forewings.

MANAGEMENT AND CONTROL

Because domestic cockroaches usually live near food, people, and in environmentally sensitive locations, it is best to prevent them from gaining initial access into these places. Infrequent invasion of just one or two cockroaches usually can be remedied quickly by capturing and destroying them or by applying a registered chemical bait, aerosol spray, or dust according to label directions. Preventing continuous invasion or suppressing established infestations usually involves a long-term program of surveillance, exclusion, improved sanitation, management practices, and chemical treatment. Professional assistance may help prevent cockroach invasion and may be required to suppress or eliminate established cockroach infestations.

It is particularly important to keep cockroaches out of commercial buildings, apartments, and other sites where they may establish sites of infestation and come in contact with people. Doors, windows, and screens should fit well and even small points of entry should be closed, caulked, or sealed. Incoming goods, especially food products, should be inspected and immediately isolated. It is important to frequently inspect all areas that are prone to cockroach infestation. If evidence of a cockroach infestation is discovered, disinfect or discard all potentially contaminated items. Paper bags, newspapers, corrugated boxes, and old rags or clothing should also be taken outside and discarded as soon as possible because cockroaches can be transported in them and they provide excellent shelter and hiding places in which cockroach infestations may develop. Similarly, wooden pallets should be stored outside, kept in a special separate room, or changed often.

Cockroaches cannot survive without food and water. Cockroaches are prevalent in commerce, especially in the transport of bulk food items, so it is important in commercial situations to reduce the amount of food available to them. Stored food should be kept in closed containers. Food scraps should be cleaned up, garbage placed in containers with tight-fitting lids and picked up at least once a week. Dirty dishes should be cleaned. Leaking pipes and standing water should be eliminated and wet mops, sponges, and rags should be dried quickly and stored properly.

Cockroaches prefer to live in undisturbed dark enclosures. Nymphs may hide in cracks and crevices less than 1 mm wide. Such openings likely to harbor cockroaches should be caulked or sealed. This includes openings into equipment and furniture, hollow table legs, wall voids, dead spaces under or behind cabinets, areas under elevators, and around pipes and conduits, wall flashings, and baseboards.

Although it sometimes requires diligent searching requiring innovative inspection techniques, cockroaches usually can be detected by carefully looking for them. Commercial sticky traps often work well for general detection and surveillance, but do not by themselves provide effective control. Application of an insecticide is sometimes needed to achieve good cockroach control, especially in and around large, complex commercial settings and places where there may be continuous introductions. Chronic infestations in homes and apartments also may require insecticide treatments. These should be of last resort rather than the first action taken. Least hazardous methods should be attempted first before ultimately resorting to more aggressive control options.

Once cockroaches become established, insecticides alone have little long-term effect unless accompanied by improved sanitation and structural upgrades.

Cockroaches are semi-social insects, aggregate in clusters guided by aggregation pheromone deposited directly and indirectly onto surfaces by nymphs and adults. Aggregation makes them vulnerable to so-called search-and-destroy techniques, such as direct sprays and vacuuming. Removal of cockroaches with a high velocity vacuum cleaner equipped with a HEPA filter is becoming increasingly popular. Specialty vacuums designed for this function have been developed and are available. It is important that the vacuum be equipped with a HEPA filter or equivalent in order to capture allergenic feces and pieces of cockroach cuticle that may be sucked into the vacuum during the vacuuming process. Vacuumed cockroaches are subsequently discarded in the trash. By its nature, vacuuming is difficult and time consuming. However, this technique may be appropriate in repetitive maintenance situations and where absolutely no chemicals are permitted.

If one finds it necessary to resort to chemical control, there is an assortment of cockroach control products available in markets, drugstores, hardware stores, home improvement centers, and nurseries. Products designed to control cockroaches that are available to consumers include traps, baits, and some liquid sprays and powders (dusts). Traps are effective for detection; baits are safe and easy to use; sprays and powders kill cockroaches on contact and leave an insecticide residue. Some sprays and powders are designed to be applied into cracks and crevices where they provide control for long periods of time. Any control product must be used in accordance with its label. Licensed professional exterminators are trained to recognize specific cockroach problems and apply insecticides in a safe and effective manner. Professionals may use special registered chemicals that are unavailable to homeowners. Because of the many factors that may be involved, it is often safer and more cost-effective to employ professional assistance.

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Notes

CHAPTER 4

BITING AND SUCKING LICE

Lance A. Durden[1]

INTRODUCTION

Lice are small (1-8 mm), wingless, dorsoventrally flattened, generally host-specific, ectoparasites of mammals and birds. Many workers recognize two orders of lice, the Mallophaga or biting (= chewing) lice, and the Anoplura or sucking lice. However, other researchers often treat each of these as suborders (or other higher taxa) within the order Phthiraptera. Phylogenetic analyses have failed to resolve this issue because there also is disagreement regarding the evolutionary relationships between these groups of lice. Sucking lice are obligate blood-feeding ectoparasites of placental mammals and have sucking mouthparts. Their tibiotarsal claws are adapted for grasping host hairs. Biting lice are a more diverse group, all of which infest the pelage (feathers or fur) of either birds (ca. 85% of mallophagan species) or mammals (ca. 15%). All biting lice have chewing, mandibulate mouthparts; but there is a wide range in the morphology of body forms and mouthparts, related to specialized host-adapted requirements. With one exception, female lice cement their eggs (nits) onto the host fur or feathers. Some Mallophaga are true blood- feeders, whereas, others subsist on particles of host feathers, fur, or skin. Because they are obligate blood feeders, members of the Anoplura are more important as vectors of pathogens than are the Mallophaga. The body louse can transmit at least three important pathogens (the causative agents of louse-borne typhus, relapsing fever, and trench fever) to humans, and three other species of sucking lice are involved indirectly in the transmission of other pathogens affecting humans. Only one mallophagan, the dog biting louse, *Trichodectes canis*, is of public health importance.

HUMAN LICE

(Figure 4-1)

Head louse, *Pediculus humanus capitis* De Geer (family Pediculidae).

Head and body lice of humans are treated here as separate subspecies, rather than separate species. This classification is accepted by most North American workers and reflects currently available evidence, such as hybridization of the two forms under laboratory conditions. In nature, however, head and body lice very rarely hybridize and gene flow between them is negligible. Some workers, especially in Europe, consider these two lice to be distinct species, *Pediculus capitis* and *Pediculus humanus*, respectively. Table 4-1 compares the main morphological characteristics of head and body lice.

Head, body, and crab lice are intimate companions of humans throughout the world, with head lice being especially common and widespread. Head lice occur on the scalp and head hair. Gravid females typically deposit their eggs on individual hairs in the nape region or behind the ears. In large infestations, however, eggs may be deposited onto hairs in any region of the scalp. Female head lice glue their eggs close to the bases of hair shafts usually within 1 mm of the skin. Hatched nits remain attached to the hair shaft and the duration of a head louse infestation can be estimated by measuring nit distance from the hair base and extrapolating the amount of time taken for the hair to grow that distance. When examining hair samples, care should be taken to distinguish harmless hair casts from nits.

Body louse, *Pediculus humanus humanus* L. (family Pediculidae).

Table 4-1 lists the main morphological charac-

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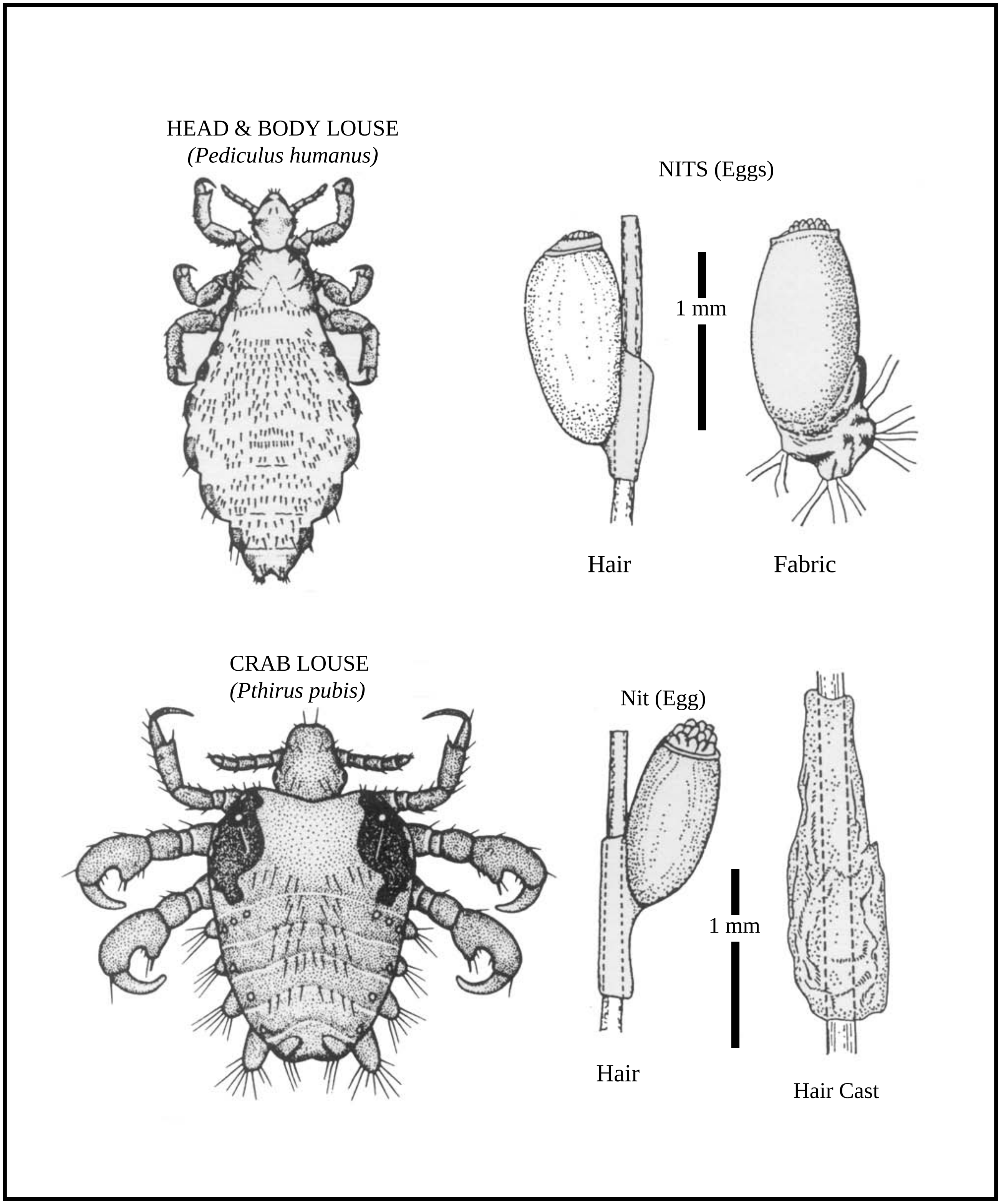

Figure 4-1. Human lice (dorsal views) (courtesy CDC, Pictorial Keys, 1966).

TABLE 4-1. Differentiation of body, head, and crab lice of humans.

	Body louse	Head louse	Crab louse
♂ body length	2.0-3.0 mm	1.0-1.5 mm	0.8-1.0 mm
♀ body length	2.0-4.0 mm	1.8-2.0 mm	1.0-1.2 mm
Abdomen	Elongate and lacking hairy lateral processes	Elongate and lacking hairy lateral processes	Short and broad with hairy lateral processes
Legs	About equal in size	About equal in size	1st pair smaller and narrower than 2nd and 3rd pairs
Body color	Grayish white	Grayish white with dark margins	Grayish white
Length of nits	0.8 mm	0.8 mm	0.6 mm

teristics of body lice, in comparison to those of head and crab lice. There is considerable morphological overlap between head and body lice and it is difficult to confidently identify single specimens without accompanying data pertaining to their location on the host.

Although body lice are cosmopolitan in distribution, control programs and globally improved hygienic standards have greatly decreased their abundance in recent decades. Nevertheless, body lice persist as common parasites of humans in several foci, including parts of North, Central, and East Africa and Central and South America. In developed countries, significant body louse infestations are currently limited largely to some homeless persons and others without access to a change of clean clothes. Although this louse infests the body and associated hairs, it is also found in clothing. In fact, female body lice preferentially deposit their eggs on clothing (especially along folds and creases) rather than on the host, a unique trait among lice.

Crab Louse, *Pthirus pubis* (L.) (family Pthiridae).

Table 4-1 lists the morphological characteristics of crab (= pubic) lice and an adult female is illustrated in Fig. 4-1. Crab lice appear to be almost as widespread globally as head lice, but because of the reluctance of some infested persons to seek medical assistance, precise data are less accessible. The tibiotarsal claws of crab lice are adapted for grasping courser hairs, especially pubic hairs but also eyelashes, eyebrows, beard, mustache, and chest hairs of men. Although infestations in the pubic region are most common, it is not unusual for these other sites to be infested and there also are several reports of crab lice infesting scalps of babies. A crab louse nit is illustrated for comparison with those of head and body lice in Fig. 4-1.

MAMMAL FEEDING LICE

(Figure 4-2)

Tropical Rat Louse, *Hoplopleura pacifica* Ewing (family Hoplopleuridae).

This louse parasitizes domestic rats *(Rattus* spp.)

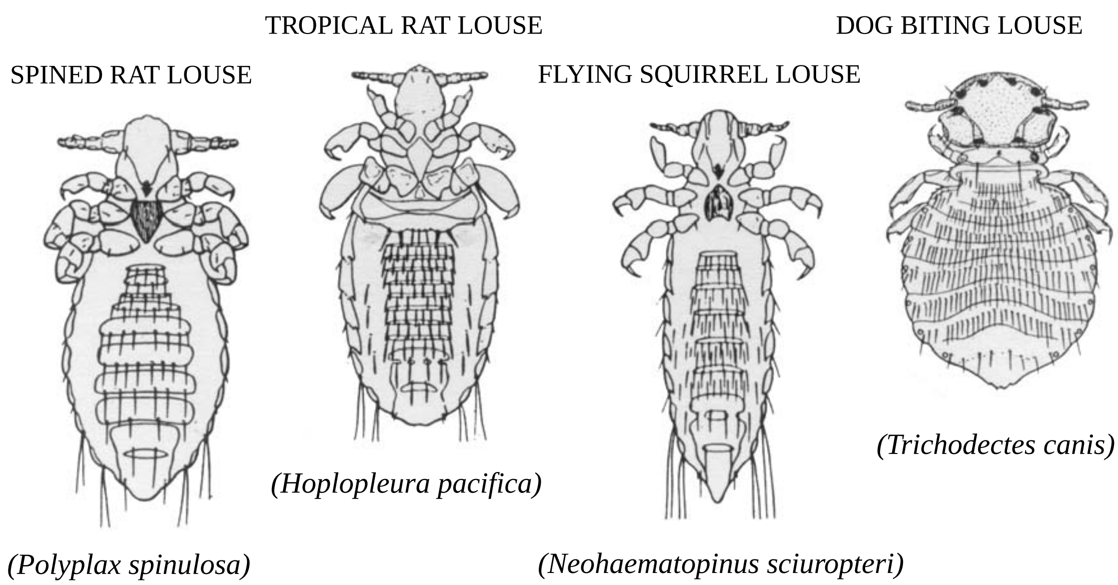

Figure 4-2. Mammal lice (ventral views) (courtesy U. S. Public Health Service).

throughout the tropical, subtropical, and warm temperate regions of the world, including most of the southern United States.

Spined Rat Louse, *Polyplax spinulosa* (Burmeister) (family Polyplacidae).

Like the previous species, the spined rat louse parasitizes domestic rats. It is found on these rodents not only in tropical and subtropical regions, but also in temperate and cool climates throughout the world.

Flying Squirrel Louse, *Neohaematopinus sciuropteri* (Osborn) (family Polyplacidae).

This louse is an ectoparasite of North American flying squirrels, *Glaucomys volans* and *Glaucomys sabrinus.* It appears to be widely distributed in North America, and probably parasitizes both species of flying squirrels throughout their ranges.

Dog Biting Louse, *Trichodectes canis* (De Geer) (family Trichodectidae).

This cosmopolitan louse parasitizes wolves, foxes, domestic dogs, and some other canids throughout the world. Unlike all of the previously mentioned species, *T. canis* is a chewing louse rather than a sucking louse. It is of medical importance because it serves as an intermediate host of a tapeworm that can parasitize humans.

LIFE CYCLE

All lice have a gradual (hemimetabolous) development in that their three nymphal instars resemble miniature adults, with exceptions of defined genitalia and other structures associated with mature individuals. Following sufficient feeding and growth, each instar must attach itself to the substrate (hair or clothing) and molt to the next instar. Successive instars are progressively larger and have a greater complement of body setae. Table 4-2 lists the main life cycle parameters for the three lice that feed on humans.

BIONOMICS

Under optimal conditions, each of the three kinds of human lice can complete one generation in about one month. However, due to control measures and the intolerance most people have for lice, optimal development times are rarely realized except perhaps under conditions of excessive human crowding and reduced sanitation that commonly occur either during times of

TABLE 4-2. Life cycle parameters for body, head, and crab lice of humans.

	Body louse	Head louse	Crab louse
Total no. nits/♀	270-300	50-150	ca. 25
Mean nits laid/♀/day	4.6	6.0	3.0
Nit incubation time	8-10 days	5-10 days	7-8 days
1st nymphal instar	4-6 days	2 days	4-7 days
2nd nymphal instar	3-4 days	2 days	4-6 days
3rd nymphal instar	4-5 days	2 days	4-6 days
Mean adult longevity	18 days	16 days	15 days

war or natural disasters. Typically, lice transfer from one individual to another during close host physical contact. However, head lice also can be transferred via shared objects such as caps, combs, hair brushes, or headphones. Crab lice usually are transferred during intimate or sexual human physical contact or occasionally via infested bed linen or toilet seats. Body lice often are transferred on infested clothing. In addition, body lice usually leave a person with a highly elevated body temperature as may occur from fever associated with a louse-borne disease. This is an important mechanism for lice to not only find a new host but also to disseminate the pathogen if they are infected. Under optimal conditions lice can survive for more than a day (rarely, a few days) off the host.

Public Health Significance

All three kinds of human lice pose public health threats. Infestation by lice is termed pediculosis; more specifically, infestation by body lice is referred to as "pediculosis corporis," infestation by head lice as "pediculosis capitis," and that by crab lice as "pediculosis pubis." Another term for infestation by crab lice is "pthiriasis." Large louse populations, although rare today in developed countries, can cause intense irritation and also may result in either anemia or louse bite allergies. Bite site redness (or blueness in most crab louse infestations) is frequent during early stage infestations, whereas, long-term infestations associated with exposure to huge numbers of body louse bites may produce a generalized skin thickening and discoloration called "Vagabond's disease." Head, body, and especially crab lice may leave small blood stains on clothing as they defecate blood-rich feces during engorgement.

Diseases Associated (Vector/Host/Reservoir)

Three major pathogens are transmitted by body lice, and each associated disease is briefly discussed below. Under certain conditions body lice also can transmit *Salmonella* spp. bacteria that cause food poisoning, including typhoid. Although head and crab lice can also transmit some of these pathogens under optimal laboratory conditions, there is no reliable evidence that they do so in nature. None of these pathogens transmitted by body lice are common today except in a few persistent endemic foci outside of North America. Nevertheless, history has repetitively demonstrated that under reduced hygienic and socioeconomic conditions, any of them could reestablish with a vengeance.

Epidemic (louse-borne) typhus, caused by the rickettsial bacterium *Rickettsia prowazekii*, is exclusive to humans and body lice. Despite extensive searches, no reservoirs other than humans have been demonstrated. Body lice become infected by feeding on an infected (rickettsemic) person. Once ingested by the louse, the rickettsiae invade gut cells where they multiply and burst free into the gut lumen. Infective rickettsiae are then voided in the louse feces deposited on the host skin during feeding. Human infection occurs when the louse bite site is scratched and infective rickettsiae in the louse feces are rubbed into the skin. However, this pathogen (and the bacterium causing trench fever, discussed later) can remain viable in dried louse feces for up to 30 days under optimal conditions. There is evidence to suggest that human infection can occur when aerosolized particles of infective louse feces are inhaled.

Early clinical signs of human infection with epidemic typhus occur 10 to 14 days after exposure and include headache, malaise, a blotchy rash on the chest or abdomen, and rapid fever onset. The rash may eventually cover most of the body. Delirium is a common late stage symptom and mortality rates in untreated epidemics range between 10 and 50%. Prompt treatment with antibiotics is usually efficacious. Major outbreaks of epidemic typhus clearly have shaped human history. For example, extensive mortality due to epidemic typhus was largely responsible for the failure of Napoleon's army to successfully invade Russia in 1812.

Louse-borne typhus also is referred to as "classic epidemic typhus" to distinguish it from two other forms of typhus. One of these, "recrudescent typhus" or "Brill-Zinsser disease," involves a recurrence of the disease in patients that previously experienced epidemic typhus. After recovery from the first typhus episode, the rickettsiae often remain dormant in human body tissues and can subsequently cause a second disease episode. Intervals between such episodes can be more than 30 years and usually occur in immigrants from regions that have experienced previous outbreaks. Because body lice are not involved in recrudescent infections, the epidemiology of this disease differs from that of classic epidemic typhus.

North American flying squirrels *(Glaucomys volans* and *Glaucomys sabrinus*) support a strain of *R. prowazekii* in nature. Infection does not appear to debilitate the squirrels and transmission of the rickettsia by the flying squirrel louse, *Neohaematopinus sciuropteri,* has been demonstrated in the laboratory. Transmission of this strain to humans has been documented in several U.S. states and the name "sporadic epidemic typhus" has been applied to these infections. However, because *N. sciuropteri* does not feed on humans, the precise mode of transmission is unknown. Because flying squirrels often roost inside attics of houses, it has been suggested that human infection may occur if viable rickettsiae from *N. sciuropteri* feces are inhaled by persons visiting these attics or sleeping adjacent to them.

Trench fever, caused by the bacterium *Bartonella (*formerly *Rochalimaea) quintana,* has been an important human pathogen during the two World Wars. It is a rare louse-transmitted pathogen today, but minor foci persist in various parts of the world. Body lice become infected while feeding on an infected person, and the bacterium is transmitted to the next host via infective feces as with epidemic typhus. Human infection can either be asymptomatic, mild, or severe with clinical symptoms including headache, myalgia, nausea, and fever. The disease can be cyclic with distinct relapses, but death is extremely rare. Antibiotic therapy is curative.

Recently, *B. quintana* infection has been discovered in some HIV-positive, immunocompromised, and homeless persons in North America and Europe. Instead of causing trench fever, infection in these cases results in reddened skin lesions (bacillary angiomatosis) or other manifestations. Because some of these patients are not infected by body lice, an alternative mode of transmission may be implicated. Epidemiological investigations into this seemingly opportunistic infection are ongoing.

Louse-borne (epidemic) relapsing fever, caused by the spirochete bacterium, *Borrelia recurrentis,* continues to be an important vector-borne disease in some developing African nations. This disease does not currently occur in North America. Infected body lice do not transmit spirochetes during defecation or feeding. Instead, spirochetes are transmitted when an infected louse is crushed and abraded into the skin by a louse-infested person. As with epidemic typhus and trench fever, humans are the only proven vertebrate reservoir of *B. recurrentis.* Clinical symptoms include fever, headache, weakness, cough, and vomiting with two to five fever relapses being typical. Successful treatment is achieved by antibiotic therapy.

Endemic (flea-borne or murine) typhus, caused by the rickettsial bacterium, *Rickettsia typhi,* is a common zoonotic pathogen in many parts of the world. Until the 1950s, this pathogen was relatively common in the southern United States and it persists today in a few of these regions, such as southern Texas and southern California. Domestic rats are the most important reservoir of infection in most regions and the pathogen is typically transmitted to humans by rat fleas. However, two species of sucking lice, *Hoplopleura pacifica* and *Polyplax spinulosa*, can transmit this pathogen from rat-to-rat. Therefore, these lice may be important vectors for maintaining the pathogen among rats in nature. Consequently, rat lice are indirectly important with respect to public health issues pertaining to endemic typhus.

The dog biting louse, *Trichodectes canis*, is the only mallophagan involved in parasite transmission to humans. It is an intermediate host of the double-pored tapeworm, *Dipylidium caninum*, that usually parasitizes dogs and other canids, but occasionally humans. Nymphal lice ingest viable *D. caninum* eggs from dog feces; and as the louse matures, the tapeworm develops to the cysticercoid stage and encysts inside it. Development of the tapeworm continues if the intermediate host louse is ingested by a canine (definitive host) when the animal grooms. However, humans can also be parasitized if they come in close contact with infected dogs. Small children may become infected as they crawl on carpets soiled with louse debris and then place sticky fingers inside their mouths.

CONTROL AND MANAGEMENT

Behavioral control is an important louse suppression mechanism. For example, avoidance of close physical contact and avoidance of sharing clothes, sheets, headphones, hats, combs, hair brushes, and other items used by infested individuals are good first lines of exclusion. Washing the clothes worn by body louse-infested persons in piping hot, soapy water will usually kill lice and nits; cold or warm water washes will not achieve this goal. A change of clean clothes and burning of old clothes of louse-infested persons can help to control reinfestation or the establishment of a new infestation. Nit combs have extremely fine gaps of ca. 1 mm between their teeth, and when pulled systematically through the hair they may dislodge nits and lice.

Chemicals that kill lice are called "pediculicides." Historically, DDT has been an effective pediculicide and its use has aborted several potential outbreaks of body louse-borne diseases. Although it is still applied in some developing countries for louse control, DDT is banned in the USA and Canada. Various formulations (e.g., gels, shampoos, sprays, fogs), currently registered can be used to control human lice. Most of these pediculicides must be used at least twice at intervals of one to two weeks because the nits often are resistant to initial applications of these chemicals. Currently registered insecticide formulations are available for controlling lice on infested furniture or sheets, etc. Unfortunately, body and/or head lice in different parts of the world have developed various degrees of resistance to some of these pediculicides. Although not yet widely approved for human louse control, ivermectin and certain insect growth regulators (IGRs) have proven to be effective pediculicides in preliminary trials. Control of rats and their lice in domestic settings and expulsion of flying squirrels from attics may decrease the incidence of endemic typhus and sporadic epidemic typhus, respectively, in humans. Also, ectoparasite control on dogs, which may harbor tapeworm-infected lice, is advisable.

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CHAPTER 5

TRUE BUGS

William W. Pitcher[1] and B. Fred Beams[2]

INTRODUCTION

The true bugs of the Order Hemiptera are represented by a large group of widely distributed insects readily identified by their piercing-sucking mouthparts and partial membranous wings (hence the name Hemiptera or partial wing). Among the bugs most likely to bite humans are the assassin and kissing bugs (Family: Reduviidae) and the bed and bat bugs (Family: Cimicidae). Plant feeding species of the kissing bugs have a specialized four-segmented beak for piercing plant tissues while the predatory species have a three-segmented beak adapted for piercing the body wall of their prey. Other bugs that have been documented to bite humans include the minute pirate bugs (Family: Anthocoridae), giant water bugs (Family: Belostomatidae), water boatmen (Family: Corixidae), plant bugs (Family: Lygaeidae), damsel bugs (Family: Nabidae), water scorpions (Family: Nepidae), backswimmers (Family: Notonectidae), stink bugs (Family: Pentatomidae), and ambush bugs (Family: Phymatidae).

ASSASSIN AND KISSING BUGS

Species of Medical Importance

The medically important species of kissing bugs in California include those species in the subfamily Triatominae that are commonly referred to as conenose bugs. These bugs are external parasites of wood rats *(Neotoma* spp.) and other smaller rodents associated with their nests. There are also several large insect predators, such as the western corsair bug *(Rasahus thoracicus)* (Fig. 5-1), the black corsair *(Melanolestes picipes)*, and the wheel bug *(Arilus cristatus)*. Each of the last three species and other closely related forms are capable of delivering an extremely painful bite produced by the injection of enzymes and other proteins that otherwise begin the process of digesting the internal organs of prey prior to ingestion.

Distribution

The true bugs are generally distributed throughout North America and California and occupy a wide variety of habitats. Since the Triatominae are associated with wood rats, their distribution is closely aligned with the *Neotoma* host species. *Triatoma rubida* has been found in Imperial, Riverside, and San Bernardino Counties associated with *Neotoma albigula*. *Paratriatoma hirsuta* is similarly confined to the Mojave and Colorado Deserts in association with *Neotoma lepida*. *Triatoma protracta* (Fig. 5-1) is more generally distributed, ranging from the southern California deserts throughout the foothills of the Sierra Nevada and Coastal Mountain Ranges. *Triatoma* spp. bites have been documented throughout its range.

Life Cycle

The true bugs complete their life cycle by gradual metamorphosis. Adults mate and lay eggs in the spring and summer. The eggs hatch within two to five weeks to a first-instar nymph. After obtaining a blood meal from a suitable host, the nymph molts and begins the second nymphal stage. After five nymphal stages, the final molt results in a winged adult, usually in the following spring. Throughout the first five developmental stages, the nymph is confined to the wood rat's nest. The winged adults may subsequently leave to mate or expand its range to other wood rat nests. The adults disperse at night and are frequently attracted to lights near residences, occasionally entering and biting the occupants inside, where they may become established as a reproducing resident.

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General Bionomics

The predatory bugs in general are considered a beneficial group of insects. Many are used as biological control agents introduced to control aphids, leafhoppers, and lepidopterous (e.g., moth) larvae. Other species are more general feeders and do not impact humans. Human bites are infrequent and typically associated with accidental contact either during outdoor activities (e.g., assassin bugs on vegetation) or while swimming (e.g., backswimmers in swimming pools, etc.). Conenose bugs, by comparison, do not normally bite during the day, but instead, will take a blood meal secretly when the human victim is sleeping unprotected. Bites to the victims lips and localized swelling have given these bugs their notoriety as kissing bugs. The bug may deposit parasite infested feces at the site of the bite, which can be rubbed into the wound or into the conjunctiva when the site of the bite begins to itch (response to injected saliva). In South and Central America, related species are implicated in the transmission of *Trypanosoma cruzi*, the causative agent for Chagas' Disease. Chagas' Disease can have a chronic debilitating affect on the population in the rural areas of the region.

Public Health Significance

Over the past forty years there has been a trend in California to move out of the cities, and construct dwellings in rural or remote areas. In addition, the increased recreational use of rural and forested areas has led to an increased exposure to wood rat nesting areas. The likelihood that these insects will be attracted to and enter residences during their dispersal flights has resulted in an increased incidence of allergic reactions to the bites and possible transmissions of Chagas' Disease. Statistics have shown that 99 percent of the documented bites have occurred inside the home, usually between the hours of midnight and 6:00 A.M. The bugs appear to be attracted to the lights around dwellings during their dispersal flights, but seek out dark and secluded areas after they land. They usually find the human host by heat receptors and chemical receptors sensitive to carbon dioxide. In many cases the victim is usually not aware that there has

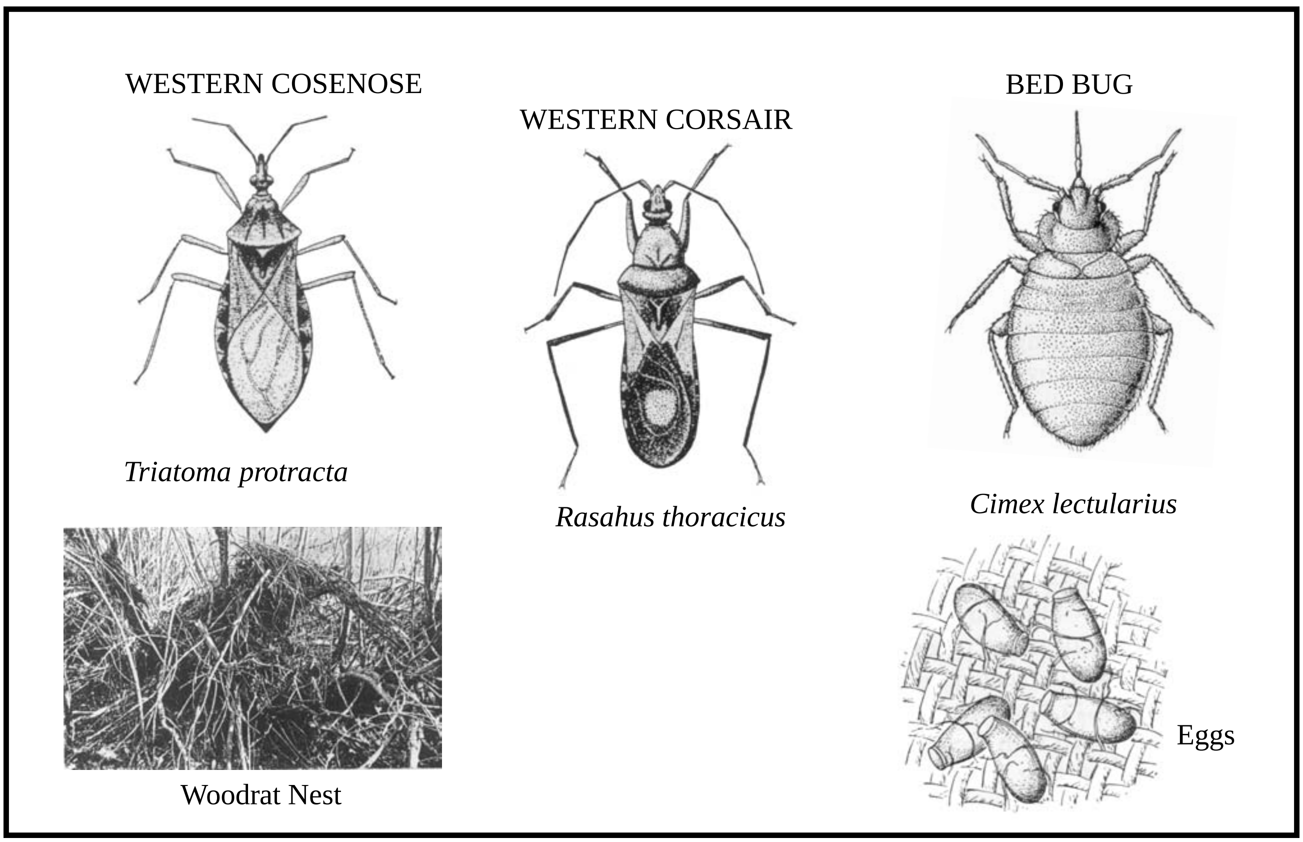

Figure 5-1. True bugs (courtesy Herms's *Medical Entomology*, 1969; and Powell and Hogue, *California Insects*, 1979).

been a bite from a conenose bug. Physicians must be informed of the habits of these insects and consider conenose bug bites in the determination of their diagnosis.

Allergic Reactions: The most significant condition resulting from a conenose bug bite is an allergic reaction resulting from injection of a foreign protein contained in the saliva of the bug that is introduced at the time of the bite. Reactions to the bite can be mild to severe, depending on the sensitivity of the victim. The severity of the symptoms may increase with subsequent bites. The symptoms commonly associated with conenose bites in order of decreasing frequency are: itching of scalp, palms or feet; swelling of eyes, tongue, or larynx; impeded speech capability; welts or rashes; nausea; fainting; pain; vomiting; fever; cramps; and death.

Chagas' Disease: Chagas' disease is a condition resulting from an infection of *Trypanosoma cruzi*, a flagellate, deposited at the site of the conenose bite by contaminated feces. Some species of the bugs have a habit of defecating immediately after taking a blood meal. The feces are frequently rubbed into the wound in response to a itching sensation at the site of the bite. The disease is more commonly associated with South and Central America. Even though documented cases of Chagas' Disease are rare north of Mexico, past surveys have found *T. cruzi* in about 35 percent of the conenose bugs in California. At least one case of Chagas' Disease has been documented from the La Grange area in Tuolumne County in 1982. Cases have also been documented from Texas. It is believed that many cases go undetected in the southwest because victims do not realize that they have been bitten, and do not seek medical attention when symptoms are experienced. The early signs of the disease are characterized by fever, fatigue, anorexia, lymphadenopathy, and hepatosplenomegaly. As the disease progresses and if left untreated, chronic Chagas' Disease results in an enlarged esophagus, colon, or heart. Death may result from the failure of these organs. The disease can be treated by administration of Bayer 2502, a drug available from the Communicable Disease Center in Atlanta, Georgia.

Control and Management

The most successful method of reducing the likelihood of a conenose bug bite, is to prevent their access to dwellings and outbuildings. A concerted effort should be made to screen all windows that can be opened, and weather protect all exterior doors. Outdoor lighting intensity should be reduced and opaque window curtains should be installed to minimize the attractiveness of the dwelling to the dispersing bugs. In areas of high wood rat populations, efforts should be made to control the wood rat population in proximity to the dwelling. Residual sprays can be applied, in accordance with the label, around windows, door thresholds, and outdoor lights. Conenose bugs encountered inside the residence can be sprayed with non-residual sprays or captured and destroyed.

BED BUGS

Species of Medical Importance

There are two genera and six species of "bed bugs" in California. Included are the common bed bug (*Cimex lectularius*) (Fig. 5-1) and other lesser species, *Cimex latipennis, Cimex antennatus, Cimex incrassatus*, the bat bug (*Cimex pilosellus*), and the swallow bug (*Oeciacus vicarius*).

General Characteristics

The common bed bug (*Cimex lectularius*) is wingless, approximately 1/4 in. (6 mm) in length with a flattened (dorso-ventral/top-bottom) oval shape, and dusky red in color that changes to a more vivid red when the insect is actively feeding. During feeding (engorgement), their bodies tend to elongate to 3/8 in. (8 mm). Bed bugs have a four-segmented antenna and beak. Like the conenose bugs, the bed bugs also have a beak specialized for sucking blood. The swallow bug resembles the common bed bug in size, but is more elongate with numerous small hairs that cover most of the body. Swallow bugs feed primarily on swallows, but are known also to feed on humans in the absence of their typical bird (avian) host. Bat bugs are similar in their behavior to swallow bugs, but feed exclusively on bats and rarely on humans.

Distribution

Bed bugs are uncommon throughout most of California being encountered most frequently in poorly maintained motels and hotels, rooming houses, and occasionally movie theaters. Most adults and immatures are moved about in infested clothing, mattresses, and upholstered furniture (e.g., couches, hide-a-beds, recliners, etc.). Since these bugs feed while the human host is sleeping, their presence is often indicated by the appearance of small blood spots on light colored sleep wear and linen. Bed bugs are active at night and when disturbed they emit a disagreeable musky odor.

Life Cycle

Bed bugs, like other Hemiptera, pass through a three stage developmental process referred to as incomplete metamorphosis (i.e., eggs, nymphs, adults). Of special interest is the reproductive behavior of these bugs because instead of the normal coupling during mating, the male instead punctures the body wall of the female and injects his sperm into a specialized structure/organ called the spermalege. From the spermalege, the sperm migrate through the body cavity to the female's genital tract. This process bears the notoriety of being referred to as "traumatic insemination." Females deposit from 10 to 50 eggs in daily batches throughout their lifetime. After one to four weeks, the eggs hatch into the nymphal stage. Nymphs feed, molt, and finally reach sexual maturity in four to six weeks if conditions remain optimal throughout their development. If not, then an additional six weeks may pass until maturity. Adults can live up to a year or longer, and are capable of surviving long periods (6 to 8 months) without a blood meal. Temperature and humidity have a significant impact on both the life cycle and life span of the adults/nymphs. At high temperatures, their survival is severely reduced. The common bed bug will not survive environmental temperatures above 45°C (112°F) and activity ceases when the temperature falls below 13°C (56°F).

Public Health Significance

Even though bed bugs feed on the blood of several hosts, there is no evidence to indicate that they are capable of transmitting diseases to humans or other animals. Bed bug bites leave a distinctive reaction that differs from flea and mosquito bites in appearance. Their bites, instead, produce a small hard wheal that is white in color accompanied by swelling and inflammation. This reaction is caused by the saliva introduced early during the feeding process. Some individuals are more sensitive to the bite than others, therefore, reactions can vary. In addition to the allergic reaction, there is also the possibility of secondary infection suddenly appearing in association with excessive scratching that introduces bacteria, etc. into the abraded area.

Control and Management

Good sanitation practices are important in the prevention of bed bugs in the home and sleeping areas. Once an infestation is confirmed, pesticide applications become the only effective means for control. Surface sprays (water base) containing malathion or pyrethrum are usually very effective for controlling bed bugs. When treating for bed bugs, spray slats, springs, and frames of the bed. Apply enough material (1% concentration) to completely cover the outer surface of infested mattresses and along the seams, creases, and tufts. Also treat nearby baseboards, openings or cracks in walls, and gaps in the floorboards. If bed bugs persist several weeks after treatment, retreat as before. If a second treatment becomes necessary, consider using silica gel products and alternative pesticides labeled for use on bed bugs.

Outside treatments for bed bugs are seldom necessary, but bird nests and bat harborages may be infested with adults and nymphs. Their presence represents a possible source for bites if the bugs search for an alternative human blood meal.

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Notes

OVERVIEW OF CHAPTERS 6-8

FLIES

Richard P. Meyer[1]

The involvement of flies (Order: Diptera) with human disease is unprecedented among insects and other arthropods with the capacity of transmitting diseases to humans and wildlife. Flies on a worldwide scale are responsible for more vector-disease deaths and morbidity in humans than all other vectors combined, including ticks, mites, lice, and fleas. Flies of public health importance are found in virtually every habitat from high arctic tundra to equatorial rain forests. Travelers to the arctic are all too familiar with the summer hoards of bloodsucking mosquitoes, buffalo gnats, and horse and deer flies, while those that venture into the tropics are similarly exposed to incessant attacks from mosquitoes, no-see-ums (punkies), sand flies, horse flies, tsetse flies, and many others.

The timing of the seasonal adult emergence of some flies, particularly mosquitoes and buffalo gnats, can effectively disrupt outdoor activities to the extent that some human inhabitants faced with overwhelming attacks are either driven indoors or forced to relocate elsewhere until conditions become more tolerable. Furthermore, some areas of the planet are virtually uninhabitable due to the presence of certain flies that vector debilitating diseases. A classic example of this phenomenon occurs in parts of Africa along river courses where the helminth (parasitic worm) causing "river blindness" is transmitted by the bite of certain species of blackflies (family: Simuliidae). Humans living along rivers colonized by blackfly larvae are bitten and simultaneously infected with the *Onchocerca* parasite that migrates via the bloodstream to the optic nerve where it causes substantial neurological damage and inevitable blindness.

Not only do some flies bite and take blood, but others are sources of annoyance by breeding in the wastes generated by human and animal activity and suddenly appearing in large numbers in backyards and parks. Among some of these annoying synanthropic (closely associated with humans) species are the house, blow, and flesh flies that develop from maggots, which predominately feed on carrion, manure, and garbage. Adult flies contacting either garbage, manure, and carrion often pick up filth disease causing agents that can be transmitted mechanically to uncontaminated foods and stored products. The larvae of some flies called "bots" undergo development as either external parasites embedded in the skin of their host or internal parasites inhabiting the lumen of the gut and intestinal tract. Still others deposit eggs and larvae into the open wounds of animals where the maggots feed on the damaged tissue often causing further damage and death in extreme cases. The human botfly or "Torsalo," indigenous to South America, develops by encysting within the skin of its human host. The developing bot breaths through its spiracles at the skin surface and obtains nutrition from fluids and blood supplied to the skin at the site of the "cyst." There are a number of highly specialized ectoparasitic flies with adults that resemble ticks. Well-known among these flies are the sheep and deer "keds" that infest the fur of their host and take blood as necessary and bat flies that inhabit the fur and wing membranes of Chiroptera.

The taxonomy of the Diptera has undergone frequent revision in recent years with particular emphasis on the arrangement of the intermediate and higher suborders. Flies typically have been divided into three suborders; the Nematocera, Brachycera, and Cyclorrhapha based upon both larval and adult morphological characteristics. However, the ambiguity with definitively separating the Brachycera from the Cyclorrhapha has compelled modern Dipterists to reorganize these two major suborders by combining them into a single suborder; the Brachycera that includes both the intermediate Orthorrhapha and the more advanced Cyclorrhapha. The Cyclorrhapha are referred to as the "circular seamed flies" by the presence of a ptilinum (eversible sac) enclosing the antennal

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area on the face. The ptilinum is inflated at emergence to burst the operculum of the puparium (pupal case), which facilitates the escape of the "new-born" adult. Once free of the puparium, the ptilinal sac is deflated and absorbed leaving the characteristic "horseshoe-shaped" suture enclosing the antennae. Both the Nematocera and Brachycera lack the ptilinum and suture artifact.

The following three chapters discuss flies of public health significance and their control. Chapter 6 deals with primitive flies (suborder: Nematocera) that for the most part take blood from vertebrates. Included in this group are the biting gnats, mosquitoes (refer to *The Biology and Control of Mosquitoes in California*, S. L. Durso, ed.), and sand flies. The following Chapter 7 discusses more advanced flies (suborder: Brachycera-Orthorrhapha) represented by blood-feeding snipe, horse and deer flies, and synanthropic soldier flies. The final Chapter 8 covers the higher flies (suborder: Brachycera-Cyclorrhapha), which includes the house flies, blow flies, bots, and keds, plus a variety of species that are of lesser importance.

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CHAPTER 6

PRIMITIVE FLIES

(Midges and Gnats)

Richard P. Meyer[1]

INTRODUCTION

The primitive flies of the suborder Nematocera are comprised of a diverse group of families that include species that are among the most important vectors of human disease. This group also includes the mosquitoes that are well-known for their involvement with the transmission of a number of human diseases including malaria, yellow fever, dengue, and encephalitis. Though other members of this group are significantly less important than mosquitoes worldwide, their association with a number of minor diseases and habit of attacking "en masse," particularly blackflies (family Simuliidae) and "punkies" (family Ceratopogonidae), makes these insects formidable vectors where encountered. Still other species of midges (family Chironomidae), crane flies (family Tipulidae), and dixa midges (family Dixidae) closely resemble and often are mistaken for mosquitoes. When examined closely, differences in their form, plus other morphological characteristics, clearly separate these "mistaken mosquitoes" from the true Culicidae. These flies lack the diagnostic characteristics of body and/or wing scales in combination with an elongated proboscis adapted for piercing skin and sucking blood. However, there are some crane flies that possess a proboscis adapted for nectar and not blood feeding. Some species of fungus gnats (families Mycetophilidae and Sciaridae) and moth flies (family Psychodidae) that do not resemble mosquitoes are often considered a nuisance as the result of their association with landscaping and domestic water sources. This chapter presents a brief review of the primitive flies with emphasis on those groups that take blood and transmit disease, mosquito-like gnats and midges that resemble mosquitoes, and others that are often encountered in and around the home.

BIONOMICS

The primitive flies are relatively unspecialized morphologically in comparison to the "higher" Diptera placed in the suborders Brachycera and Cyclorrhapha. Adults are typically elongate with a tubular abdomen, the antennae are either thread-like (filiform) or feathery (plumose), the thorax is noticeably robust, and the male abdomen bears distinctive claspers used in mating. The wings of these flies also are less specialized with relatively simple arrangements of the costal, radial, median, and cubital veins. Among some of the smaller species (e.g., blackflies in the family Simuliidae), most wing veins are either absent or limited to several prominent veins that support the leading edge (costa). The typically elongated larvae of Nematocera are either flattened or tubular tapering from a distinct sclerotized head capsule to a blunt abdomen that bears a number of auxiliary structures related to biological requirements (e.g., abdominal gills in aquatic species).

The feeding habits of the adults vary considerably, ranging from species of blackflies and "punkies" that take blood, species that feed on nectar sources and related plant exudates, species that feed on decaying vegetable matter, to species with adults that do not feed but live for sufficient time to mate and lay eggs. Likewise, the diet of larval stages is similarly diverse with species that function as predators in both terrestrial and aquatic situations; species that feed on decaying organic matter and fungi (saprophytic); and species that feed on algae, detritus, and other suspended food particles present in their aquatic breeding sources.

Dispersal and related flight capabilities of most primitive flies vary from sedentary wingless crane flies to highly mobile species of blackflies and "punkies." Species of the latter two groups of flies are capable of

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flying great distances to obtain blood from hosts that are many miles from established breeding sites. However, most species disperse over short distances and generally persist within their immediate environment. Limited dispersal is usually related to the delicate nature of the adults that are highly susceptible to desiccation. This environmental vulnerability is also linked to both daily activity rhythms and seasonal emergence patterns. Most nocturnal species that fly during the summer obviously avoid daytime heat and low humidities by delaying all activities until after sunset and before sunrise. During the day, the adults seek moist resting sites in shade. Many often congregate under the eaves of houses and on shaded porches of residential dwellings. In the field, adults rest close to the ground in green vegetation and on the upper surface of leaves of plants growing along water courses, lakes, and ponds.

LIFE HISTORY

The biological diversity of primitive flies includes species that are adapted to either terrestrial (e.g., fungus gnats) or aquatic environments (e.g., blackflies) in the larval stage. This dichotomy in breeding requirements has resulted in the evolution of seasonal patterns of adult emergence to coincide with either the availability of standing and running water or the presence of moist to saturated terrestrial substrates like mud, turf, and humus. These aquatic to semiaquatic conditions are necessary to facilitate growth, but more importantly to protect eggs, larvae, and pupae from desiccation. Both "punkies" (e.g., *Culicoides* spp.) and "black gnats" (e.g., *Leptoconops* spp.) that bite desert residents in the spring and early summer are dependent upon standing water and saturated soil extending several feet below the soil surface.

Oviposition habits of primitive flies vary with their aquatic versus terrestrial breeding requirements. Egg hatch occurs following either a period of temperature conditioning associated with overwintering, or inundation or saturation of both the oviposition and larval development sites. Upon hatching, the larvae begin feeding on the food resources present in their immediate surroundings. The larvae of one particular aquatic group, the blackflies (family Simuliidae), have "fan-shaped" antennae specially adapted for collecting food particles suspended in the water of rivers and streams.

All primitive flies undergo complete metamorphosis. The number and duration of successive instars varies greatly according to species coupled with prevailing environmental conditions. Pupation in aquatic species occurs either at the bottom (benthos), water surface (neuston), or shoreline (psammon) of the breeding source while terrestrial species pupate in moist soil or other comparable substrates. Upon emergence, the adults seek protective sites in moist shaded conditions to allow the "soft" cuticle and wings to harden.

PUBLIC HEALTH IMPORTANCE

Besides mosquitoes, other forms of blood-feeding primitive flies also are involved with the transmission of disease agents that have a debilitating effect on humans, including causing occasional fatalities. The *Phlebotomus*, or sand flies of the family Psychodidae, transmit a number of viral, bacterial, and protozoan pathogens to humans worldwide. "Punkies" or "no-see-ums" of the family Ceratopogonidae are also known to transmit a number of important disease causing microbes to humans. In California, there are no recorded instances of primitive biting flies, other than mosquitoes, that have been demonstrated to transmit pathogens to humans. However, "punkies" *(Culicoides* spp.) effectively transmit epidemic hemorrhagic disease (EHD) virus to deer and bluetongue virus to sheep.

Allergic Reactions to Gnat Bites

The bites of "blackflies" and "punkies" often produce a severe localized reaction at the site of the bite. Sensitive individuals may experience intense itching, swelling, and seeping ulcerations that may persist for several weeks if topical applications of either antihistamines or corticosteroids are not used. Most people will notice some localized discomfort at the site of the bite that usually subsides in less than one week. Bites to the face, around the eyes, and inside the ears produce the most intense discomfort followed by lesser reactions to bites on the extremities and torso.

Allergic Reactions to Midge Products (Dried Body Parts)

Sensitive individuals either contacting (dermal exposure) or inhaling (respiratory exposure) the fragments may experience allergic reactions. Suspended body fragments contacting the skin can cause a rash to appear or blistering in extreme cases. Likewise, if inhaled, a mild or severe respiratory allergic reaction can occur, which may require immediate treatment in some cases.

Bite Prevention

The are a number of personal protective measures to preclude gnat bites and the allergic reactions they may elicit. When gnats are actively feeding, protective clothing covering the exposed arms and legs along with a fine mesh mosquito/gnat head net can deter most gnat bites. In extreme cases, when attack rates are exceptional, heavier clothing may be required. Wearing gloves may be necessary to protect the back of the hands and the soft skin between the bases of the fingers. When applying repellents containing the active ingredient DEET (N,N-diethyl-M-Toluamide), do not apply to the sensitive areas of the face around the lips and eyes, but apply the product to your hands and then rub it onto the cheeks, forehead, ears, and back of the neck. Applying some repellent to the brim and sides of a hat or cap also can be effective for repelling "indirectly" without having to apply DEET directly to exposed skin.

TAXONOMY

The taxonomy of the primitive flies is based largely on a combination of the morphology of the antennae, mouthparts, and wing veins. Specific adaptations of the mouthparts for blood feeding is seen in the biting gnats while other non-blood feeding forms possess functional chewing-type mouthparts for feeding on different substrates ranging from plant nectars and exudates to animal secretions. The antennae have undergone little specialization with structural features remaining simple. Most species have either annulate or filiform antennae represented by a simple elongated shaft comprised of articulated cylindrical and/or beaded segments. Wings in this group have extreme modification in the location and consolidation of the costa, radial, and median veins. Male genitalia also have undergone specialization with the claspers being modified for grasping and subsequently interlocking with female secondary sexual accessory structures. Morphological differences in male terminalia are used to separate the genera and individual species. Females are more difficult to identify because they lack the morphological identity associated with their genitalia. Their taxonomy is based more upon differences in body form, coloration, antennae, and wing patterns.

PRIMITIVE FLIES OF PUBLIC HEALTH IMPORTANCE

Midges and Blood-Feeding Gnats
(Figure 6-1)

Blackflies or "Buffalo Gnats"

The blackflies (family Simuliidae) in California are comprised of a group of species represented in a number of major genera that include principally *Prosimulium, Cnephia,* and *Simulium.* The distinctive "humpbacked" adults, which gives them their name as "buffalo gnats," are small (1/16-1/8 in.; 2-3 mm) and colored in different shades of grays, browns, blacks, and yellows; and the abdomen often bears distinctive dark lateral spots on the middle segments. Wings are unmarked and spear-shaped with all major support veins limited to the leading edge. A majority of our species emerge in the spring and early summer from running water sources. Emergence continues along both latitudinal and elevational gradients with some species not appearing until middle to late summer at higher elevations in the Sierra Nevada. Adult females are capable of flying several miles from river and stream breeding sources in search of a blood meal. Unlike females, males do not take blood. Among some of California's more common species are *Simulium aureum, Simulium virgatum, Simulium trivittatum,* and *Simulium vittatum*. During the spring, *Simulium griseum* can be a pest in desert areas of southern California.

Daytime attacks of blackflies can be horrific during times of peak emergence. The author still remembers that while growing up in Newfoundland and trout fishing near Argentia, the incessant spring attacks by blackflies were so intense that the numerous bites behind the ears would bleed profusely. The application of repellent had little affect on reducing the bites. The best relief was finally achieved by wearing a fine mesh mosquito netting that covered the head and neck. It was also discovered that wearing lightweight gloves also was effective in protecting the back of the hands and the soft skin between the bases of the fingers.

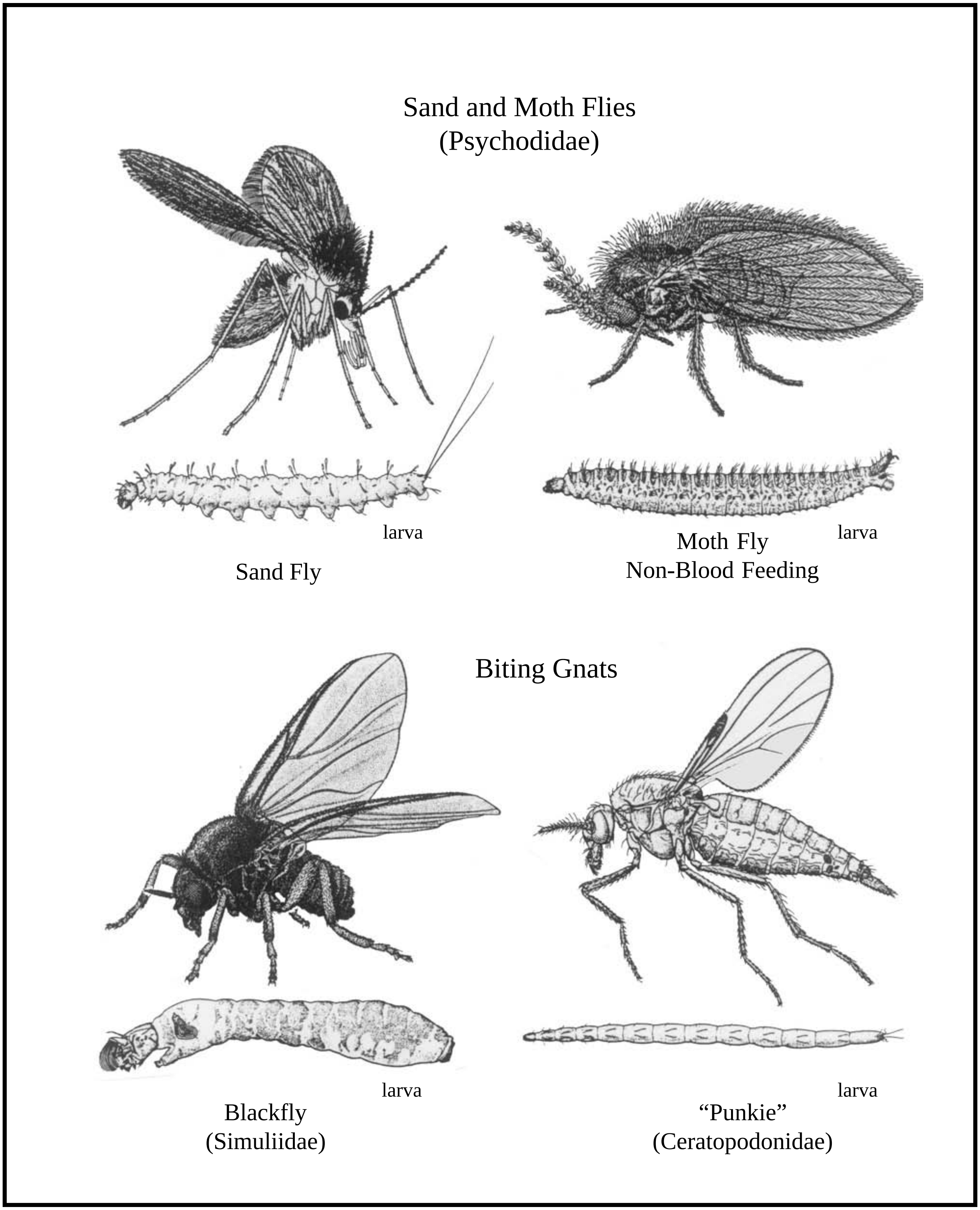

Figure 6-1. Midges and blood-feeding gnats (courtesy *Manual of Nearctic Diptera*, Monograph No. 28, Agriculture Canada, 1981).

Larvae of blackflies are morphologically unique by their elongated shape (1/4-3/8 in.; 5-10 mm) and slight constriction in the middle combined with the presence of prolegs on the thorax, specially adapted antennae used in gathering food particles, and ventral sucker located at the base of the abdomen. The ventral sucker used for securing the larva to the surfaces of rocks and aquatic vegetation is actually comprised of a circlet of tiny hooks called "crochets." Larvae are capable of producing strands of silk secreted from the salivary glands that can be used as a lifeline if the larvae accidentally become dislodged from the attachment site.

Female blackflies deposit their eggs (200-500) in running water environments. The creamy white eggs, which hatch in about four to five days, are either laid directly on the water surface or glued to the surface of rocks, aquatic vegetation, and other objects that are present in the nursery stream or river. Upon hatching, the young larvae attach themselves to objects in swift currents where they will usually remain for the duration of their development. The number of larval instars is variable, but most species molt from four to seven times before pupation. Under normal circumstances, the duration of the larval development period may span one to several weeks. Pupae are attached to the underside of submerged objects and continue to receive oxygen from the water via filamentous gills attached to the mesothoracic spiracle. The duration of the pupation period is also variable and may require anywhere from several days to weeks depending upon species and water temperature.

Punkies or "No-See-Ums"

The punkies (family Ceratopogonidae) are another group of minute (1/16 in.; 2 mm) biting flies. The adults in the genus *Leptoconops* are colored black with either clear or milky wings, while adults in the genus *Culicoides* are variously colored in blacks, grays, and tans with the wings often patterned in diagnostic concentric blotches and spots. Females are notorious painful biters that are seldom noticed biting until after they have engorged. This attribute of their "stealthy" feeding behavior prompted their alias as "no-see-ums." Species that are important in California include the Valley black gnat *(Leptoconops torrens)* and the "Bodega gnat" *(Leptoconops kerteszi)*, plus a number of *Culicoides* gnats, of which *Culicoides variipennis* is perhaps the most widespread and medically important. Like the blackflies, both *Leptoconops* and *Culicoides* are capable of long-range dispersal to mate, blood feed, and lay eggs.

The Valley black gnat is notorious for its presence during the spring and early summer in communities adjoining adobe soil areas of the Central Valley. The Bodega Gnat is similarly troublesome, but to coastal residents living near salt marshes and estuaries that support abundant larval populations in the damp soil adjoining the wetlands. Valley black gnat larvae do not breed in moist soil near standing water, but breed in association with saturated adobe soils that characteristically form drying cracks by summer. During exceptional years, when black gnats emerge in the billions in the southern San Joaquin Valley, outdoor activities may be unbearable from late spring to early summer. On occasion, oil field operations along the Kern River north of Bakersfield historically have been disrupted by the attacks on well maintenance and drilling crews that had to curtail work activities until the attacks subsided.

The eggs of *Leptoconops* are deposited on the surface of either moist alkaline *(L. torrens)* or saline soils *(L. kerteszi)* and hatch within several days to a week under normal circumstances. After hatching, the young larvae begin to bore into the soil to complete their development by feeding on organic nutrients that percolate downward from the surface. Complete development of *L. kerteszi* requires about one year with pupation occurring eight to ten days prior to emergence. A number of generations can be produced in a productive year between the months of April and October. Larval development of *L. torrens* is significantly longer and usually requires two years to complete a single generation. Pupation occurs near the soil surface where drying cracks form to assist with the emergence process. Production of this species overlaps years with emergence occurring in May and June. Female *Culicoides* deposit their eggs either directly on the surface of the aquatic breeding source or just above the water line.

Sand Flies

The blood-feeding sand flies (family Psychodidae) were once considered all members of the genus *Phlebotomus* until a reexamination of their taxonomy revealed noticeable differences in Old World versus New World species. Species indigenous to the New World (e.g., North and South America) are now placed in the genus *Lutzomyia*. New World sand flies are typically psychodid in appearance with "hairy" bodies and wings that give them their "moth-like" appearance. The genus is represented in California by several species with *Lutzomyia californica* being widespread, and *Lutzomyia stewarti* and *Lutzomyia vexator* from the Central Valley, surrounding foothills, and adjacent coastal habitats.

Not much is known of the biology of our native species. Eggs are deposited in sheltered humid (nearly 100% RH) situations that protect newly hatched larvae from desiccation and provide adequate nutrients to assure their complete development. The larval diet includes organic debris, animal excrement, decaying plant material, and fungi. Larvae complete development in six to eight weeks during which time they molt four times. Adults emerge in about ten days and females begin host seeking in about two to three days post-emergence. The entire life cycle takes from seven to ten weeks under optimal conditions.

NON-BLOOD FEEDING GNATS, MIDGES, AND MOSQUITO-LIKE FLIES

(Figures 6-2 and 6-3)

Crane Flies

Of the non-biting primitive flies discussed in this chapter, the crane flies (family Tipulidae) are perhaps the singular group that is most often mistaken for mosquitoes. Their appearance, habit of flying to lights at night, and entering homes invariably attracts attention to their presence. Larger species often have been mistakenly referred to as "mosquito hawks," a definite "fable" that relates to their assumed "predatory" habits of eating mosquitoes. Adult crane flies are not predators and most feed either on nectars and plant excretions, or simply not feed at all. Species vary in size and coloration from giant species (e.g., *Holorusia rubiginosa)* with a wing length of 40 mm to minute species (e.g., *Dasymolophilus)* with a wing length of 2 mm. Regardless of size, all are characterized by a common wing vein pattern, long legs, absence of ocelli, and a "V"-shaped suture on the top (dorsum) of the thorax.

Crane flies breed in a variety of situations ranging from aquatic, semiaquatic, and terrestrial. Species encountered in urban environments are usually those which breed either in turf, compost, flower beds, or potting soil. Associated aquatic species are restricted to breeding in ornamental ponds, storm drains, and flood channels. The larvae of some well-known turf species (*Tipula*) that occasionally damage lawns are often called "leatherjackets" by horticulturists.

Little has been published on the life histories of most North American Tipulidae. What is known includes a generalized developmental scheme that describes egg hatch to occur in six to 14 days, four larval instars prior to pupation, and a pupal period of approximately five to 15 days. Locally, there may be considerable variation in developmental rates driven by climate, temperature, nutrient availability, and population densities. Crane fly larvae are typically tubular shaped with a retractable head capsule, and the rear of the abdomen often bears "fleshy" projections that are diagnostic for identification of genera along with distinct differences in the shape of the spiracular disc.

Dixa Midges

The dixa midges (family Dixidae) are discussed briefly because of their superficial resemblance to mosquitoes. The larvae also closely resemble those of anophelines. Dixids are most often encountered in rural rather than urban settings with the exception of the presence of widely distributed species that often colonize domestic flood channels in large cities. The adults are distinguished by wing venation characteristics in combination with a short slender abdomen, simple (filiform) antennae, and chewing-type mouthparts. Also, there are no scales present on the wing veins and body.

California species of dixids are represented in several genera of which *Dixa* and *Dixiella* are the most common. Though highly localized, one species, *Dixiella californica*, is widespread in northern and central California and is replaced by *Dixa modesta* in southern California. The larvae of both species assume a "U"-shaped posture on the water surface where they presumably feed on organic materials that accumulate on the surface film. The larvae of both are capable of "crawling" about on exposed rock surfaces and emergent vegetation by pushing ("carrying") a film of water as they proceed.

After mating, females will deposit their ovoid eggs (16-110) enclosed within a gelatinous mass just below the water surface of the breeding source. Hatching occurs four days later with the larvae undergoing four molts until pupation. The duration of the pupal period occurs in as little as 17 hours during the summer or

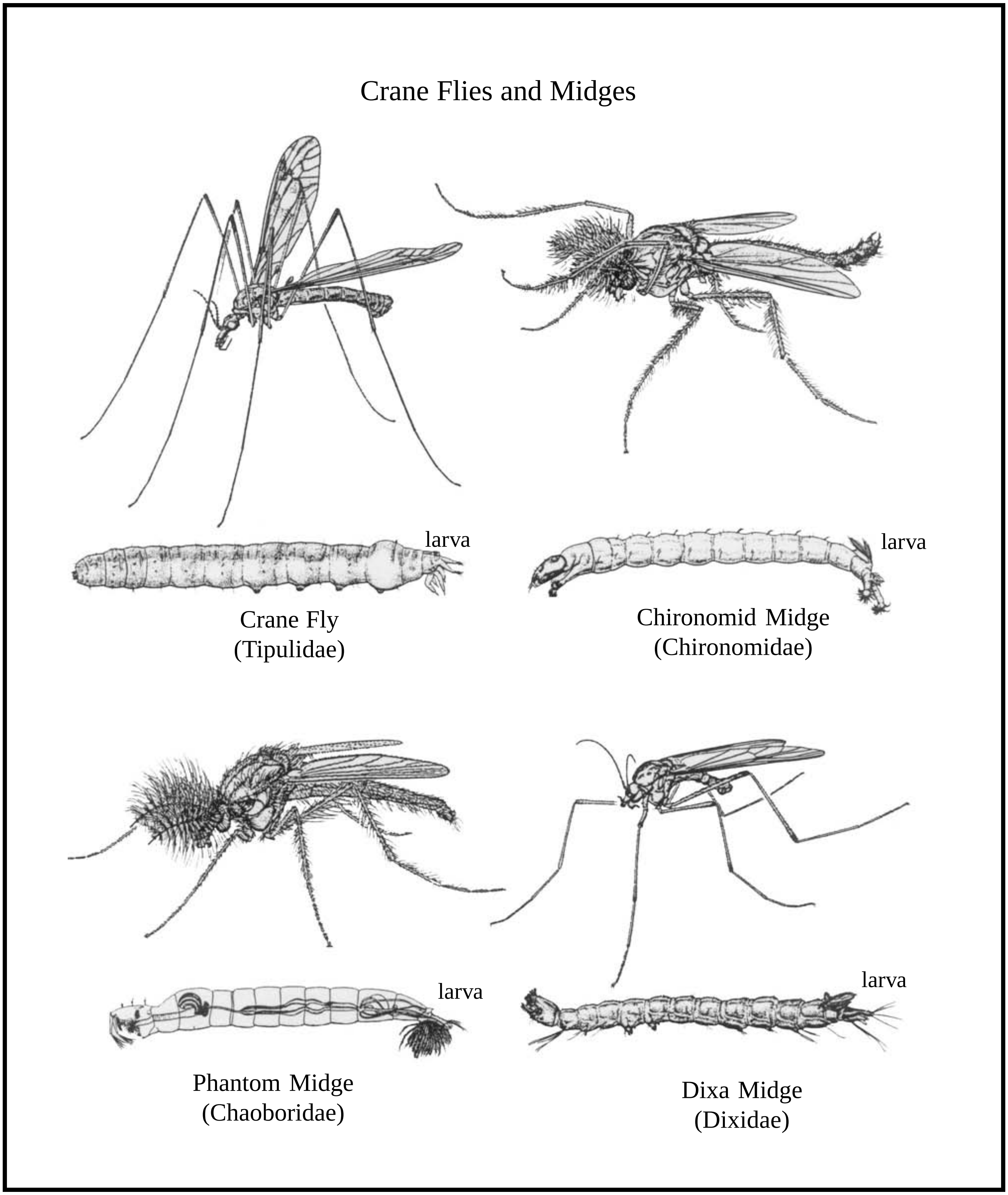

Figure 6-2. Non-blood feeding gnats, midges, and mosquito-like flies (courtesy *Manual of Nearctic Diptera*, Monograph No. 28, Agriculture Canada, 1981).

typically longer at five days during late fall and early spring.

Phantom Midges

This often overlooked group (species in the family Chaoboridae) is of little significance with the exception of the problems that one species causes to residents living around Clear Lake in northern California. The Clear Lake gnat *(Chaoborus astictopus)* exists most of the year as abundant larval populations in the relatively shallow and algal laden waters of Clear Lake. However, when the mature larvae pupate by early summer, the resulting emergence produces incredible "white" hoards of adults that literally inundate the surrounding communities of Lake Port, Clear Lake, Kelseyville, and Lucerne. Virtually all the frontages of buildings facing the lake become shrouded in the masses of accumulated adults that aggregate at these sites to rest during the day. This situation is made worse by the added attraction of adults to outdoor frontage lights at night. Historically, the Lake County Mosquito Abatement District has dedicated a majority of its operational and pesticide resources to controlling the larvae in an effort to preempt the massive adult emergence in the summer at the time of peak tourism.

Midges

Like crane flies, midges (family Chironomidae) are frequently mistaken for mosquitoes. The adults are colored in cremes, yellows, greens, tans, browns, and black with contrasting markings on the thorax, abdomen, and legs (tarsi). Adults range in size from minute species (1/16 in.; 2 mm) to relatively large forms that can exceed 1/2 in. (13 mm). Adults are characterized by the absence of body and wing scales, the presence of mouthparts adapted for chewing, the presence of a "Y"-shaped suture on the top (dorsum) of the thorax (scutum), wings that are held in an inverted "V," an abdomen which is longer than the wings, and forelegs that are held spread and slightly erect. This characteristic posture of the legs often leads to the confusion of these extremities as the insect's antennae.

Although adult midges are often confused with mosquitoes, their larvae bear no resemblance to mosquito "wigglers" because they lack the diagnostic siphon (excluding anophelines). Unlike mosquitoes, they possess prolongs at the end of the last abdominal segment and ventrally on the first thoracic segment at the base of the head capsule. Midge larvae obtain air via abdominal gills or through their cuticle (skin). The

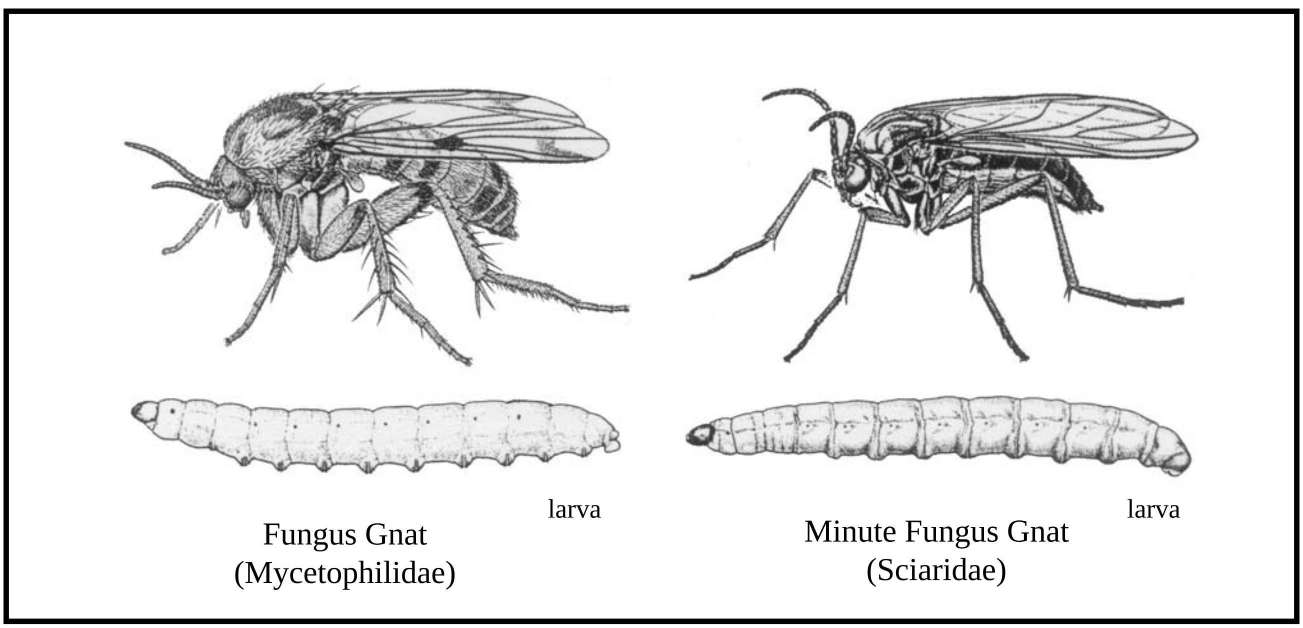

Figure 6-3. Fungus Gnats (courtesy *Manual of Nearctic Diptera*, Monograph No. 28, Agriculture Canada, 1981).

larvae of *Chironomus* are often referred to as "blood worms" because the haemolymph ("blood") contains hemoglobin that "stores" oxygen for use when available dissolved oxygen in the water becomes drastically depleted.

Female midges deposit their eggs on the water surface in gelatinous clusters, strands, and masses depending upon the species. In the summer, the eggs hatch within several days and the larvae begin feeding on a diet consisting of microorganisms, decaying organic matter, algae, and other midges (predatory species). There are four larval instars and the last instar transforms into the pupa. The duration of each individual instar is influenced by prevailing water temperature and nutrient availability. Under optimal conditions, larvae can complete their development in seven to ten days. Similarly, the pupal stage lasts anywhere from one to several days, or longer under cooler temperature conditions.

Adults often undergo mass emergence in the spring and summer with populations reaching tremendous numbers in both rural and urban settings. Inhabitants near lakes, ponds, storm channels, and oxidation ponds often have to contend with the seasonal emergence of midge hoards. At dusk, huge mating swarms may appear along trails and bike paths that adjoin breeding areas. Midges are more typically attracted "en masse" to lights where they become a nuisance by their presence and later by the accumulation of their bodies mixed with layers of spider webbing.

Moth Flies (Fig. 6-1)

Species of moth flies (family Psychodidae) that do not take blood are often the source of complaints when they appear indoors around toilets and sinks. Although these flies scarcely resemble mosquitoes, their presence indoors frequently raises concern from homeowners that are not familiar with the breeding habits of the larvae. The distinctive adults (1/8 in.; 3 mm) are "hairy" over the wings and body. When at rest, the diagnostic spear-shaped wings are held tent-like over the body. Larvae are unique among aquatic flies in having either three oval plates or rows of spines on the top (dorsum) of each body segment.

The larvae of aquatic species typically breed in the fowl water sources, which have accumulations of leaf and other organic sediments or rocky bottoms. Moth flies frequently become a nuisance at sewage and water-treatment plants that incorporate rock filtration beds as part of the routine water purification and recycling process. Our common species belong to the genus *Psychoda* with others represented in *Pericoma* and *Telmatoscopus*. Species in the latter two genera are commonly found in rural areas where the larvae inhabit lakes, ponds, streams, and rivers. Moth flies *(Psychoda* spp.) in residential settings are associated with fouled ornamental ponds and out-of-service swimming pools. Large populations are known to develop in the flooded crawl spaces of raised foundation homes following the rupture of water pipes or sewer drains. If left unattended, flooded foundations also can produce house mosquitoes *(Culex pipiens* and *Culex quinquefasciatus)* along with the moth flies. Seldom used sink, bathtub, shower drains, and toilets are frequently colonized by moth fly larvae that feed on organics and algae that accumulate in both sediment and vent traps.

Dark-Winged Fungus Gnats

The dark-winged fungus gnats (family Sciaridae) also called "root gnats" are small delicate flies (1/16 in.; 1-2 mm) that are most often the source of complaints associated with indoor plants, greenhouses, and subterranean mushroom gardens. Adults are drab in appearance colored in shades of browns and blacks with wings often tinted brown to smoky. The group is widespread in California and represented by numerous genera including the more common *Sciara*, *Scatopsciara,* and *Lycoriella.* The larva (1/4 in.; 6 mm) of *Sciara* is whitish, tapered at both ends, and the tip of the abdomen is slightly inflated (bulbous). Sciarid larvae normally feed on decaying plant material, fungus, and animal excrement.

Fungus Gnats

Fungus gnats (family Mycetophilidae) are larger than Sciaridae and more commonly encountered. The shiny adults (1/8-1/4 in.; 3-6 mm) are colored in yellows, reds, and browns with the wings either clear, tinted, or patterned with dark blotches. They are identified by the diagnostic wing venation, but more noticeably by the presence of elongate coxae and prominent tibial spurs. Seasonally, fungus gnats appear late in the winter and early spring at which time they are most often confused with mosquitoes that normally fly later. Their early appearance is linked to the moist and humid environmental conditions required for their survival and breeding. The larvae are much like those of sciarids, except larger (1/4-1/2 in.; 4-12 mm), and similarly breed in association with fungus. Some species also will consume decomposing vegetable matter and animal feces. Our native representatives of this group (e.g., *Mycetophila, Boletina,* and *Exechia)* are predominately cool weather forms that are well suited to the moist environments of the coastal, foothill, and mountainous regions of California.

MANAGEMENT AND CONTROL

The integrated approach to managing primitive flies, particularly, blood-feeding species, presents a number of impracticalities to applying both non-chemical and chemical measures. Treatment of blackflies in the larval stage is feasible if chemicals (e.g., Bti) can be applied to moving water sources prior to pupation after which control is not possible using either an IGR like methoprene or biological represented by Bti. Therefore, any control to preempt emergence must be performed prior to pupation. This situation is consistent for midges (Chironomidae and Dixidae) and other species of aquatic gnats (Psychodidae) that can be controlled effectively by the application of any of these two chemical types, but prior to pupation. Midge control in ornamental lakes and ponds and urban flood channels is often performed in response to preclude adult emergence that often creates a considerable "mess" around lighted structures, particularly illuminated porches, patios, and security areas bordering breeding sites.

Controlling black gnats that breed in adobe situations is economically and physically impractical. Larvae spend most of their development several feet below the surface and only migrate to the surface prior to pupation and subsequent emergence via "mud cracks" that form as the adobe dries.

Historically, blackfly adults have been treated in rural and urban situations around homes by fogging streets and letting the material disperse to contact the adults in flight. This method never provided any level of sustained relief, with adults quickly repopulating affected areas within one to three days after each application. However, fogging sometimes actually worked in rare instances when a species emerges over a short period of several days, and the application is timed and staged to contact the adults at the right moment.

For species representative of economic sciarids, mycetophilids, and terrestrial tipulids that breed in moist humus, soil, and occasionally in indoor potting soil, there are a number of conventional insecticides that are formulated for soil applications. These chemicals diluted in water penetrate through the surface of the substrate to contact the eggs, larvae, and pupae. Unlike Bti and methoprene, these compounds also kill both the eggs and pupae.

Environmental Management

The application of environmental management to control primitive flies of public health importance requires augmenting existing environmental circumstances in a manner that either precludes target species colonization or exposes sensitive life stages to conditions (e.g., desiccation, enhanced predation, etc.) that cause their timely death. Controlling gnats and crane flies that breed in the soil or moist humus simply involves frequent tilling of the soil in excessively moist flower beds or occasionally allowing the soil to dry sufficiently to kill the larvae/pupae. Crane fly larvae that breed in turf are nearly impossible to exclude using environmental methods. Unfortunately, heavy infestations normally require applications of an appropriate larvicide. Indoor plants present a more difficult problem with sciarids that are well adapted to potting soil conditions. The best recommended action is to either reduce watering schedules or replace existing plants and infested potting soil.

Controlling blackflies and "punkies" (*Culicoides)* by environmental methods presents problems associated with managing water associated with breeding sites. Alterations to running water for reducing blackflies is feasible if flows can be adjusted along with eliminating riffle components from major channels between runs. This action will not eliminate all breeding, but will limit larval attachment sites to areas where the water carries sufficient dissolved oxygen for minimal respiration. Otherwise, riffles are highly oxygenated with rocks and cobble that are optimal attachment sites for the larvae. In contrast to blackflies, "punkies" generally breed in standing water with high alkalinities brought on by desert conditions, or often saline conditions in upland salt-marsh habitats. Seasonal drainage of these sites via ditching or enhanced percolation can be effective if environmentally acceptable and if all management action is implemented before the larvae pupate.

Exclusion

In areas where blackflies, black gnats, "punkies," and non-biting midges are a seasonal annoyance to outdoor activities, exclusion becomes a reasonable option by denying these flies access to activity areas. Porches, patios, and picnic areas enclosed with small mesh (20 mesh for gnats) screening, and/or tenting will provide an effective barrier against biting gnats during the day and after sunset. The selection of mesh size is critical because some of the small species of these gnats and midges can penetrate through standard #12 mesh window screening.

In addition to exclusionary screening, the attractancy of midges and gnats to white and mercury vapor lights placed at activity sites, including porches, can be significantly reduced by replacing existing white lighting with either sodium vapor or yellow incandescent types of bulbs. Commercially available "bug zappers" provided with an electrified grid and aided by ultraviolet (UV) attraction bulbs are **not recommended** and provide little diversion of flies from activity areas. Instead, these types of diversion traps may actually worsen the situation by luring disproportionately large numbers of gnats and midges to the area where only a small number will be killed by the electric grid.

Public Education

Informing residents living in midge and gnat prone areas will significantly help with the understanding of the seasonal nature of species associated with bites and nuisance problems. From year-to-year they will then be able to "anticipate" that certain species will be out and about and that outdoor activities will be negatively impacted from several days to several weeks. At the same time, providing information on nuisance species is important for lessening the concern with gnats and midges that do not blood feed, but "appear" as forms that are associated with attacks and subsequent itching bites. This information also will tend to dispense pending phobias and associated misperceptions of non-biting species.

SURVEILLANCE

Surveillance of primitive flies historically has been limited to economic and public health species that directly impact human welfare. The flies in this select group are represented by those species that take blood and/or transmit disease agents. Because of the often disruptive annoyances created by these flies and disease consequences, considerable effort has been invested in the development of surveillance methods for quantifying populations of biting gnats, primarily blackflies. The results obtained from a variety of trap development and comparison studies (blackflies) indicate that no singular trapping method is totally effective for sampling either adult or immature populations. Unfortunately, the best method of sampling blackfly adults is with human bait where host-seeking females are collected either by a mouth- or mechanical-type aspirator. This method, though extremely effective, carries ethical considerations by deliberately exposing humans to vector bites. A reasonable alternative to human bait collections is the use of carbon dioxide-baited traps like the CDC-type CO_2 (dry ice) baited trap.

Methods for determining larval population abundances have been developed for blackflies and midges. Quantifying the number of larvae from subsamples taken from breeding sources can be used as a reasonable projection of probable adult emergence with risks being assessed to the appearance of blackflies and/or midges in sensitive areas. For blackflies, the risk can be measured as a likely attack rate and resulting disruption of outdoor activities. Similarly for midges, risk can be assessed as the nuisance likely evoked by the adults when they "invade" nearby residential areas.

Since the larvae of these flies either colonize or attach themselves to different aquatic substrates, such as submerged rocks, vegetation, and logs, various types of artificial substrates have been used which allow larvae to establish on the surface in densities similar to those found on them naturally. The types of artificial substrates include simple rectangular plates (6 in. sq.) either suspended in the water column or anchored to the bottom of the source to more complex multiple layer plate units placed similarly. Alternative methods of quantifying the abundance of primarily blackfly larvae involve the use of either rocks placed in a removable wire tray or thin plastic streamer (simulates algae/water grasses) that can be periodically removed from a riffle habitat and inspected for the presence of larvae.

Notes

CHAPTER 7

BRACHYCERAL FLIES

(Horse Flies, Snipe Flies, and Relatives)

Richard P. Meyer[1]

INTRODUCTION

Human populations living at more northern latitudes and in the mountains are all too familiar with the painful bites inflicted by horse, deer, and snipe flies. These flies, belonging to the suborder Brachycera (Orthorrhapha, in part), are provided with mouthparts that literally slice into the skin of the host to sever capillaries and cause the blood to pool at the skin's surface where it is ingested by the sponging action of the labellum. Although the mouthparts are often embedded in the skin during engorgement, the cutting action of the mandibles produces a very painful bite plus profuse bleeding that is enhanced by the introduction of an anticoagulant saliva. Many species feed predominately on ungulates, particularly deer and other large mammals, including humans. Not all of the brachyceral flies are known for their painful bites because the larva of one particular non-biting species of soldier fly (family: Stratiomyiidae) produces a rare form of enteric myiasis in humans. This chapter briefly discusses the bionomics, taxonomy, and medical importance of Brachycera and practical methods intended to reduce human and domestic animal contact. Overall, effective management of the blood-feeding forms is difficult because most breed in environmentally sensitive wetlands and along the margins of rivers, creeks, and streams.

BIONOMICS

Horse and deer flies of the family Tabanidae are considered aquatic to semiaquatic insects because larval development of most known species occurs in water (mud and moist soil). Tabanid larvae are associated with all types of wetlands, including fresh and saltwater marshes, estuaries, lakes, and ponds and occasionally streams, creeks, and rivers. Although both horse and deer flies are closely related, they differ in size with horse flies being distinctly larger and more robust. The hind tibia of deer flies bear preapical spurs (spines) that are absent in horse flies. Visually, deer flies in the genus *Chrysops*, are recognized by the presence of brown to amber patches on the wings of most species. Most horse flies have either clear, smoky, or opaque black wings. The coloration of adult horse and deer flies varies considerably with many species conspicuously marked in browns, blacks, grays, tans, and yellows. The shape of the abdomen of either horse or deer flies is universally flattened with some sexes and species varying in abdominal width and the amount of taper from the anterior to posterior segments. Abdominal patterns among species also are highly contrasting with different combinations of dark bands, spots, and blotches. Larger species of horse flies usually are brown to black with smoky wings.

The sexes of horse and deer flies differ both morphologically and behaviorally. Males typically do not feed on blood, but obtain nutrition (e.g., carbohydrates) by feeding on the nectars produced by flowers and "exudates" that accumulate on the surface of damaged fruit, leaves, stems, and branches. Males, and occasionally females, are attracted to mud as a source of water on hot summer afternoons. The large compound eyes of males converge at the top of the head, a condition which is termed "holoptic." Female compound eyes are by comparison more widely spaced, hence "dichoptic," with a significant frontal gap at the frons and vertex. Adults are strong fliers and capable of long-range dispersal to seek hosts for blood meals, mate, lay eggs, and avoid environmental conditions that may adversely impact their

[1]Orange County Vector Control District, 13001 Garden Grove Blvd., Garden Grove, CA 92843.

survival. Some species of horse flies are among the fastest of the flying insects with documented air speeds in excess of 25 to almost 40 m.p.h.

The snipe flies (family Rhagionidae) are smaller than horse and deer flies and cylindrical in profile. Their legs are noticeably more elongate and thin, and the wings are clear without dark colored markings. The body coloration of blood-feeding species (e.g., *Symphoromyia)* is uniformly gray to light brown without contrasting patterns on the thorax and abdomen. Most species are aquatic with larval development of blood-feeding *Symphoromyia* occurring in intermittent woodland creeks and streams.

The soldier flies (family Stratiomyiidae) are distributed worldwide. Larval development occurs in a wide variety of situations ranging from aquatic to terrestrial in association with decomposing vegetable matter. The adults of most species are brightly colored in shades of yellows, greens, reds, browns, and rarely blues and black. The wings are often patterned in reds, browns, and black which give larger species a "wasp-like" appearance. Their close resemblance to wasps is mimicked behaviorally by the likeness of their flight to that of vespids and sphecids. One particular black species, the black garbage fly *(Hermetia illucens),* (3/4 in.; 20 mm), which mimics black mud daubers or thread-waisted wasps, has paired clear "windows" in the anterior segment of the abdomen and white legs (tibiae). This species breeds in garbage and grass clippings, and on occasion accidental human cases of enteric myiasis are known to be associated with either children or adults consuming rotting fruit containing the larvae.

LIFE HISTORY

Horse and Deer Flies

Females deposit their eggs either on emergent vegetation, mud, or overhanging tree branches where the eggs are attached to the underside of leaves. Upon hatching, larvae drop to the water surface, swim to the bottom, and begin feeding on sediments rich in decaying organic matter. Larvae hatching from eggs deposited directly to shoreline substrates (mud and/or decaying vegetation) will begin feeding immediately on the available nutrients. Although most species feed on decaying organic materials, the larvae of *Tabanus* horse flies are predaceous on snails, earth worms, insects, and crustaceans. Larval development varies among species with some requiring one to three years to mature and others one to two months during the summer. The number of instars or times a larva molts ranges between four and nine. Mature larvae usually move away from the submerged organic layer to pupate one to two inches below the surface of the drier earth bordering the shoreline of the breeding source. Tabanid (includes both horse and deer flies) larvae (1-2 in.; 25 to 50 mm) are white and evenly tapered on either end with darkened inflated joints that separate the segments. Adults emerge from pupae in five days to three weeks depending upon the species. The longevity of adults is seasonal and varies with the species; but overall, females live longer than males with some individuals surviving several weeks or longer.

Snipe Flies

The life histories of most snipe flies are poorly known and what information is available is limited to only a few semiaquatic and terrestrial species. Adults of blood-feeding *Symphoromyia* are active from March through June, and most species produce only a single (univoltine) generation per year. Females of these species deposit their eggs either on the surface of vegetation or on other alternative substrates that line temporary woodland streams. Since the larvae also breed in the wet soils and mosses along temporary streams that dry up by early summer, larvae (or possibly pupae) are carried through to the next fall-winter rainy season. Mature larvae (1/2 in.; 12 mm) are "maggot-like" with distinctive pointed heads and blunt posteriors. Four to six tapered processes extending beyond the last body segment encircle the spiracles. Adults live for several weeks under favorable conditions and perhaps longer in moist shaded canyons where blood meals are easily obtained from deer, cattle, and other vertebrates.

Soldier Flies

The eggs of the black garbage fly *(Hermetia illucens)* are deposited on the moist surfaces of decaying fruits, "digesting" grass clipping compost, and other similar organic substrates. Eggs hatch in about two to five days, and larval development requires an additional one to two weeks. Pupation occurs within the last larval skin. The larvae (1 in.; 25 mm) of this species are distinctive by their boat-shaped and tapering outline combined with being flattened dorsally. The adults are relatively long-lived (about one month) and capable of dispersing several miles to mate and reproduce.

PUBLIC HEALTH IMPORTANCE AND DISEASE RELATIONSHIPS

Bite Trauma and Allergic Responses

The bites of horse, deer, and snipe flies are considered traumatic because the wounds produced by the cutting actions of the mandibles cause considerable localized tissue damage and bleeding. The damage caused by the bite is further intensified by the introduction of saliva containing anticoagulants that promote bleeding. At the same time, additional proteins are introduced that can cause severe allergic responses in susceptible humans. The bleeding, burning, and subsequent itching often produce discomfort for several days to a week following the bite. Severe reactions to the bites, in combination with scratching to relieve the itching, can lead to either raised seeping ulcerations or secondary infection if untreated.

The incessant attacks, particularly those of horse flies, are known to seriously impact the vigor of horses and cattle during the spring and early summer. Blood loss due to repetitive bites produces a number of clinical and behavioral side effects that collectively reduce the animal's ability to combat disease. Many animals in "high" horse fly areas often become either ill or abort following massive attacks.

Vector-Borne Diseases

The blood-feeding habits of the horse and deer flies and the similar behavior exhibited by snipe flies predisposes these flies to vectoring blood-borne pathogens to mammals, including humans. Although most species occasionally bite humans, their actual involvement with transmitting disease agents is restricted to large mammals with humans being infected rarely by accidental bites. Transmission of known veterinary pathogens by horse and deer flies has been well documented. By comparison, snipe flies are not known to transmit agents of any recognized disease of wildlife even though they bite animals (e.g., deer) that are afflicted with a number of diseases that are transmitted by ticks, mosquitoes, blackflies, and horse and deer flies.

Among the more well-known pathogens transmitted by tabanids, are those that cause Anthrax, Tularemia, and Anaplasmosis. Anthrax is a bacterial *(Bacillus anthracis)* disease of cattle that also can affect numerous other species of domestic and indigenous wildlife and humans. Horse flies of the genus *Tabanus* have been incriminated in transmitting these bacteria either mechanically from contaminated mouthparts (e.g., mandibles and labella) or from contaminated feces that are rubbed into the skin at the site of the bite. Humans sometimes bitten by anthrax "infected" horse flies will develop a malignant pustule at the location of the bite. Tularemia is another bacterial *(Francisella tularensis)* disease that is transmitted by the bite of deer flies *(Chrysops* spp.), particularly by one species, *Chrysops discalis*. These bacteria are more commonly transmitted by either the bite of infective ticks and fleas that maintain these disease agents enzootically among lagomorphs (e.g., rabbits and hares). In the absence of either ticks or fleas, rabbit-to-rabbit, or hare-to-hare transmission, enzootic maintenance has been facilitated by infected *C. discalis* in the western United States. Besides rabbits, tularemia bacteria also affects other reservoir species that include field mice, ground squirrels, canines, sheep, and a variety of game birds (e.g., quail and grouse). One significant disease of cattle, anaplasmosis or "infectious anemia," caused by *Anaplasma marginale* can be transmitted by both horse and deer flies. This disease is more common in the southeastern states with a documented history of its impact on cattle ranching and milk production.

Enteric Myiasis

Enteric myiasis is the occurrence of insect larvae (maggots) in the gastrointestinal tract of either an obligate or accidental host. The larvae of the black garbage fly *(Hermetia illucens)* are occasionally involved with accidental infestation of the intestinal tract of humans who live in squalid conditions where overripe fruit containing the fly larvae is consumed primarily by children. When ingested, the larvae pass through the stomach and enter the intestine where they can cause some discomfort and associated gastro-intestinal disorders. The larvae are eventually passed with little or no permanent post-infection side effects.

TAXONOMY

Horse and Deer Flies

The taxonomy of horse and deer flies is based largely on the morphology of the eyes, antennae, body ornamentation (e.g., color patterns on the abdomen and thorax), and wing markings. The eyes of horse flies are often colored in solid shades or cross-banded with browns, greens, blacks, and yellows. Eyes of deer flies are even more remarkably patterned with metallic greens and golds and radial patterns of blacks, yellows, and greens. The abdomen can be variously colored with different arrangements of spots and bands that complement the thorax, which is either unmarked or striped in contrasting darker colors. Wings also are variable with some species having from totally smoky or clear wings to those marked with contrasting spots or patches of either brown, yellow, or black. A majority of male and female deer flies are sexually dimorphic with differences in their eyes, wings, and color patterns.

Snipe Flies *(Symphoromyia)*

Snipe flies are similar in appearance with little differentiation in gross morphology that makes identification not an "easy" process. Differences in species is largely associated with the uniqueness of adult genitalia combined with subtle differences in coloration, chaetotaxy (patterns of body hairs and spines), antennal morphology, and wing venation.

Soldier Flies

The morphology of soldier flies is substantially diversified in comparison to other closely related families with species that do not show significant variation in both form and color. The black garbage fly is unique by its elongate form and the presence of "windows" in the anterior segment of the abdomen. Overall, soldier flies are separated on the basis of differences in their antennae, body form, wing coloration, and wing form.

SPECIES OF PUBLIC HEALTH SIGNIFICANCE
(Figure 7-1)

This section includes a number of species that are known to cause discomfort to humans and wildlife in California. Excluding the black garbage fly, which has been discussed previously, specific biological information on a selected number of species is presented herein.

The Western Horse Fly *(Tabanus punctifer)*

There are several species of horse flies distributed throughout California in predominately cooler environments associated with foothill and montane habitats. Perhaps the best known among the western species is the western horse fly, which inhabits almost every moist environment from sea level to about 6,000 feet in the mountains and Great Basin (northeastern California). The adults (1 in.; 25 mm) are distinctively colored black, including the wings, with the pronotum bright gray. The dark colored eggs are deposited on the underside of vegetation overhanging the aquatic breeding source. Hatching occurs in five to seven days and the larvae fall to the water surface, swim to the bottom mud, and begin feeding as predators on the macroinvertebrates (e.g., snails, insect larvae, crustaceans, etc.). Larval development requires approximately one year with pupation occurring in the spring followed by adult emergence. In warmer parts of the state, development may be accelerated with sufficient time to produce two to three generations during the late spring, summer, and early fall.

Deer Flies *(Chrysops* spp.)

Deer flies are distributed throughout California in association with wetlands and riparian environments. Most species are locally troublesome and seasonal with biting attacks peaking in the late spring and summer depending upon location. Among some of our common species are the widespread *Chrysops discalis*, *Chrysops hirsuticallus* from the Central Valley, *Chrysops latifrons* from the southeastern deserts, *Chrysops bishopi* from the eastern Sierra, and *Chrysops coloradensis* from the northern Sierra and Cascades. The species of greatest concern is *C. discalis* because this deer fly, which breeds in alkaline situations, is known to transmit tularemia causing bacteria to humans and wildlife. The males are dark brown to black with heavily mottled wings. Females, by comparison, are colored light brown to tan with two contrasting tan stripes on the thorax and paired spots on each abdominal segment that become progressively smaller on the rear segments. The wings are mottled in light brown with the "discal cell" clear. Eggs are deposited on the tips of emergent aquatic vegetation (e.g., sedges) and hatch in about three to seven days. Upon hatching, the young larvae drop to the water surface and swim to the bottom where they will feed on vegetable matter and other organic food resources. Normally, one generation is produced each year with a second generation often produced in the Central Valley and eastern Sierra. Mature larvae seek pupation sites one inch below the surface of moist alkaline soils near the water's edge. Adults subsequently emerge in two to three weeks under favorable conditions.

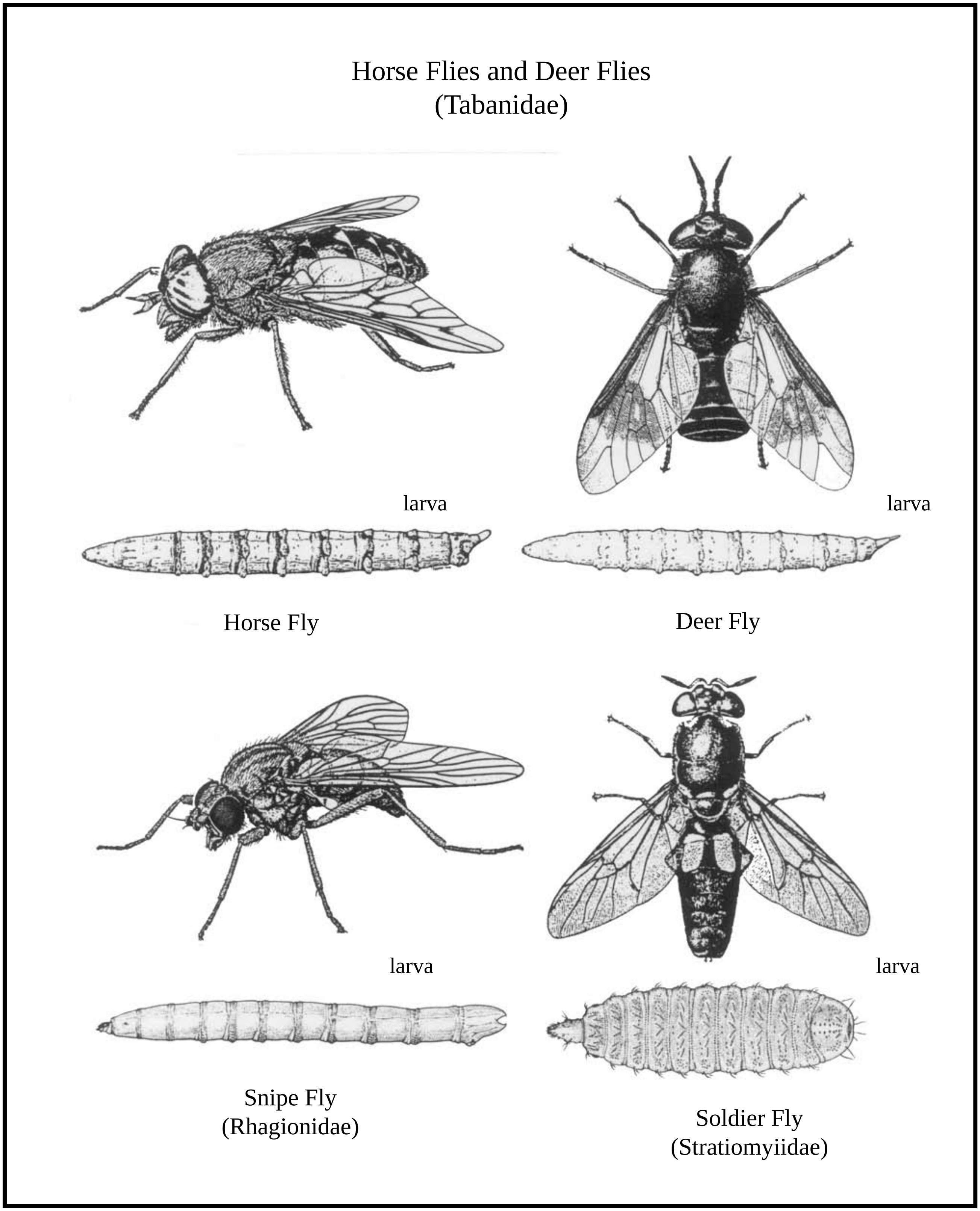

Figure 7-1. Brachyceral flies of public health significance (courtesy *Manual of Nearctic Diptera*, Monograph No. 28, Agriculture Canada, 1981).

Snipe Flies

Biting snipe flies of the genus *Symphoromyia* are represented by a handful of species in California with northern representatives causing considerable discomfort to humans and wildlife wherever they are encountered. Both *Symphoromyia plagens* and *Symphoromyia atripes* are widespread in California with the former being the most prevalent species involved with biting humans in woodland and riparian habitats. Two additional species, *Symphoromyia pachyceras* and *Symphoromyia limata*, have limited distributions with *S. pachyceras* found in the northern part of the state and *S. limata* in southern California. During the spring, both *S. pachyceras* and *S. limata* can become locally annoying to hikers and residents that either visit or live along sheltered foothill and mountain streams. The adults of all four species are similar in appearance with an overall gray body coloration and clear wings. A noticeable "pterostigma" or forewing spot is located just beyond the middle of the leading edge (costal region) of the wing.

MANAGEMENT AND CONTROL

Effective chemical control of horse and deer flies is largely impractical as a consequence of their breeding requirements and environmental sensitivities linked to applying pesticides indiscriminately to wetlands breeding sources. Furthermore, a chemical agent must be applied that is capable of penetrating well into the silted layer of the larval microhabitat and at the same time not negatively impact associated nontarget species. The impracticality of effective chemical control options has resulted in the adoption of alternative measures that involve either source reduction or exclusion. Chemical repellents, protective clothing, and mosquito netting also can afford acceptable protection against tabanid and snipe fly bites.

Source Reduction

Modifying breeding sites is the best method of managing horse and deer flies in peridomestic situations. Water and vegetation management in roadside ditches, filling swales (e.g., flooded depressions) in pastures, and increasing the embankment to limit shoreline in farm ponds can reduce the suitability of these sites to breeding. There are no known programs for practical tabanid control via source reduction in rural and "wild" areas because environmental and wildlife protection laws severely limit any type of habitat degradation that may be linked to either vegetation removal, filling and leveling activities, and permanent drainage.

Exclusion

Exclusion involves the application of barriers that prevent horse, deer, and snipe flies from contacting host animals and humans. For campers, fishermen, hikers, and rural residents this means confining relaxation activities to screened enclosures. Excluding tabanids from cattle and horses is not practical, except that screened barns and corrals at some expense can give the animals temporary relief when removed from open pastures.

Repellents and Other Protective Measures

Since tabanids and snipe flies are essentially rural insects, recreational activities that are impacted by these biting flies can be tolerated by preventing bites. Options for bite prevention include either wearing protective clothing that covers the arms and legs, mosquito netting to cover the face and neck, or applying DEET (N,N-diethyl-M-Toluamide) based repellents directly to clothing and sparingly to the face and exposed legs and arms. Repellents used in conjunction with mosquito netting, long sleeve shirts, and long pants provide the best overall bite protection.

CHAPTER 8

HIGHER FLIES

(House Flies, Blow Flies, and Relatives)

Richard P. Meyer[1]

INTRODUCTION

The higher flies are represented largely by a complex assemblage of different species particularly adapted to obtaining nutrients as adults and immatures from a variety of resources that span the range of host blood and live tissues, carrion, waste products, and decomposing vegetable matter. Their close association and capacity to assimilate this variety of nutrients enables most species to quickly breed and produce tremendous populations when optimal environmental conditions prevail. Along with their inherent reproductive capacity and nutritional requirements comes the likely association with filth and vector-borne diseases that necessarily evolved from feeding on blood, refuse, and animal wastes as the focal reservoirs of fly-borne parasites and microbial pathogens. The relative dispersal capacity of the higher flies, particularly that of synanthropic (in association with humans) forms like house and blow flies, enables them to readily access resources (hosts, carrion, etc.) distributed over a wide geographic area and at the same time either "transmit" or "carry" pathogens/parasites to new hosts in the process. These two relationships alone account for the exceptional efficiency at which fly-borne disease agents are both transmitted and disseminated in nature.

BIONOMICS

Flies are familiar insects distributed throughout the world where they are maintained ecologically by local conditions supporting their development. Most species proliferate under warm conditions that accelerate larval development and maximize adult activity, including mating, feeding, and flight. Tropical environments afford flies with exceptional conditions that allow for year-round breeding, while colder environs limit breeding and other activities to the summer months. Warmer versus cooler climates also regulate the rate at which fly-associated diseases multiply in their respective vectors with transmission occurring sooner in warmer compared to cooler seasons.

Populations of synanthropic species like the house fly and some blow flies are capable of explosive growth when provided with abundant larval food resources. Other species that rely upon animal rather than refuse may never become abundant or emerge "en masse" to create a public health problem. However, species' populations that do manage to reach abundant levels inevitably disperse from breeding sources and scatter in search of new sites. Most Cyclorrhapha are capable of sustained flight that enables them to fly upwards of five to 20 or more miles from breeding areas. Even greater dispersal distances are possible if assisted by strong tail winds associated with storm fronts and seasonal changes. Once dispersed in the environment, adult flies must survive to feed, mate, produce eggs, and find suitable oviposition (egg laying) sites. During the summer months, adults are normally short lived (1-2 weeks) at the warmer air temperatures and progressively survive longer (2-3 weeks) if the temperature gradually cools. Longevity definitely is extended during the fall and spring (potentially 4-5 weeks) and winter at southern latitudes where activity occurs year-round. Overwintering temperate and boreal species (i.e., those species that cease reproduction when prohibited by "freezing" air temperatures during the winter season) have developed a number of strategies and mechanisms to assure survival from late fall until the following spring. Some species overwinter as either inseminated females, pupae, larvae, or eggs depending upon the duration of the overwintering period and special requirements for egg hatch and larval development, coupled with larval nutritional requirements (e.g., garbage versus animal tissues).

[1]Orange County Vector Control District, 13001 Garden Grove Blvd., Garden Grove, CA 92843.

LIFE HISTORY
(Figure 8-1)

The higher flies undergo complete metamorphosis that includes development from an egg, larva, pupa, and adult. An interesting aspect of higher fly life histories involves the larval stages and their peculiar adaptations, plus the fact that some higher flies do not lay eggs but deposit live larvae directly to the surface of their food resources. Eggs deposited by oviparous (egg laying) species usually hatch in from one to two days. The subsequent growth and molting by the larval stages varies considerably among species and is dependent upon existing environmental conditions (particularly temperature), nutrient availability, and competition from other larvae/species. The larval development phase normally includes five distinct instars with increasing differentiation occurring with each successive molt. The final instar eventually ceases feeding and seeks a sheltered site to pupate. Pupation occurs inside the last larval skin that forms the puparium. Within the puparium, metamorphosis occurs with the conversion of the larva to the adult. When the adult achieves full development, it literally bursts free of the puparium via the ptilinum (eversible "balloon-shaped" sac extruded from the front of the head) and crawls to a suitable site to expand its wings and cure the cuticle.

The flesh flies (family: Sarcophagidae) are unique among the Cyclorrhapha because the female deposits live larvae instead of laying eggs. This condition of depositing live young is termed ovoviviparity (ovoviviparous species) and also occurs in notable species, such as the sheep botfly (family: Oestridae) in Europe and North America and tsetse flies (family: Muscidae) in Africa.

TAXONOMY

Identification and taxonomic relationships among the higher flies are complex with separation of species, genera, and families requiring a detailed knowledge of both adult and larval morphology. The larvae (maggots) of many species are difficult to identify because the mature instar lacks sufficient morphological differentiation to easily distinguish it from closely related forms. Larvae that can be identified with certainty are recognized by a combination of characters that include: l) the shape and nature of the terminal abdominal spiracles (spiracular button); 2) the location and shape of the mouth hooks retracted inside the head (cephalic) capsule; and 3) either the presence or absence of setae or "processes" attached to the body segments.

Adult flies by comparison are exceptionally complex insects with distinct differences in body and wing form, mouthparts, antennae, and bristles (setae and spines) ornamenting the head, thorax, abdomen, and legs. Species of higher flies (Cyclorrhapha) are similarly constructed with a prominent head and dorsolateral prominent compound eyes; aristate type antennae; sponging-lapping type mouthparts; wedge-shaped wings with veins located towards the leading edge; tubular-shaped thorax covered with spines and setae; wedge-shaped abdomen also ornamented with spines; and legs with prominent tarsi, claws, pulvilli, and spines. Body coloration ranges from bright metallics (greens and blues) to drab grays and blacks. Some species have accent patterns consisting of stripes on the thorax and various checkered patterns on the abdomen.

When identifying a house fly using taxonomic keys, for example, the morphological characters that are examined include wing venation plus either the presence or absence of "calypters;" the type of mouthparts (sponging); the presence of an arista on the antennae; the arrangement of spines on the dorsum of the thorax, face, and occiput; and the length and shape of the maxillary palpi.

DISEASE AND PUBLIC HEALTH RELATIONSHIPS

The biological attributes of the higher flies and their feeding and reproductive habits prime this group as logical carriers of vertebrate pathogens. This is especially true for synanthropic flies that contact carrion, feces, and decomposing vegetable matter that are rich in all types of microorganisms associated with causing human and veterinary diseases. The nutritional and feeding habits of the larvae (maggots) of some species requires feeding on either living, necrotic (dead) tissue, or on nutrients present in the gastrointestinal tract of the host. This accidental or obligatory association of larvae/maggots with their respective hosts is termed myiasis (refer to section on myiasis). Surprisingly, the blood-feeding species of Cyclorrhapha in North America and California (e.g., stable fly and horn fly) are not known to biologically transmit any pathogenic disease. These two species, however, occasionally transmit some well-known disease agents mechanically via contaminated mouthparts.

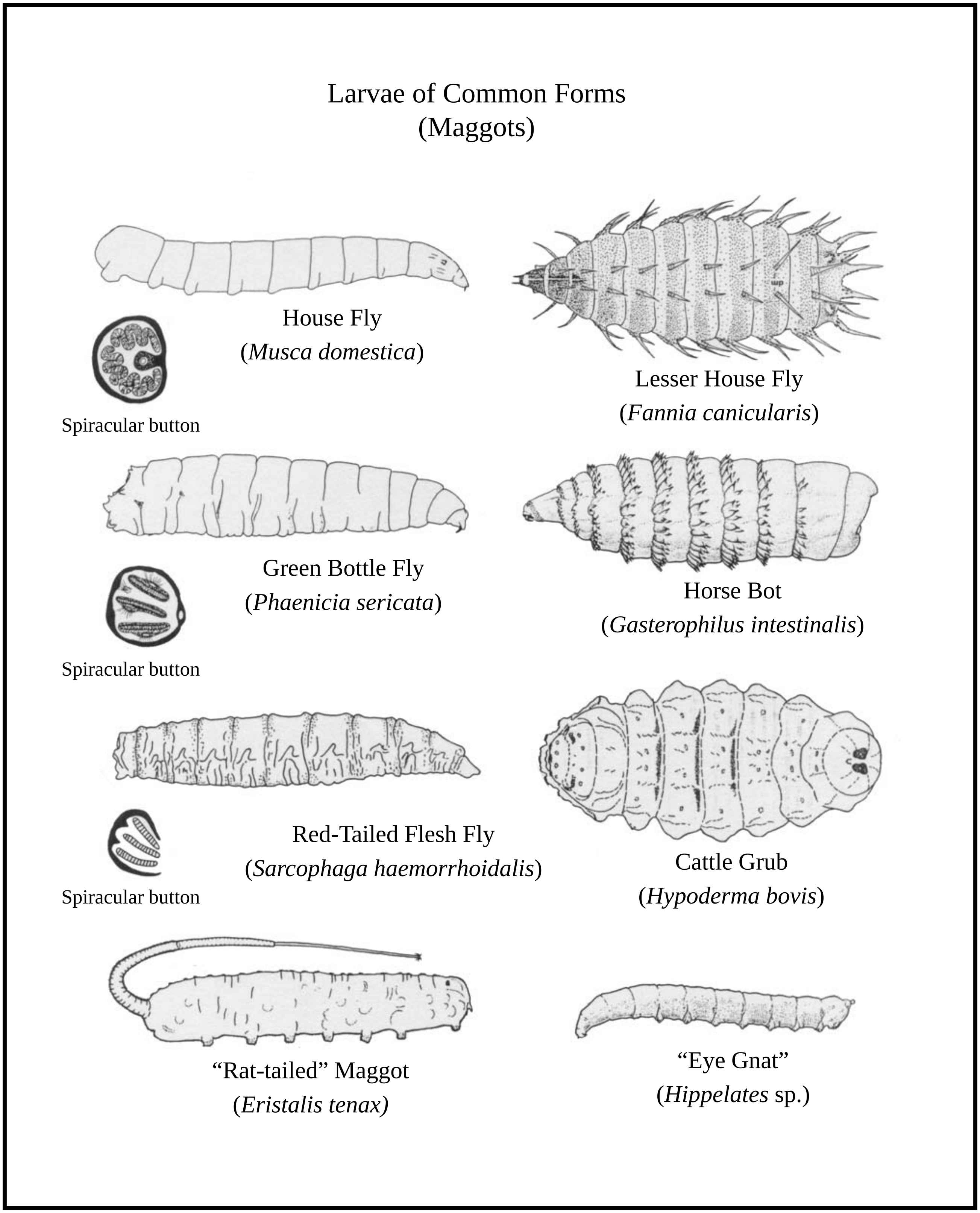

Figure 8-1. Larvae of common forms of higher flies (courtesy *Manual of Nearctic Diptera*, Monograph No. 28, Agriculture Canada, 1981).

Annoyance Factors

When house flies and other related forms emerge and begin flying about, they often congregate in large numbers at sites that are attractive because of existing shelter and food. This behavior also places these flies in situations where they can become a considerable nuisance in parks, at picnics, and residential backyards. Most humans are decidedly intolerant of the presence of house flies hovering around patios, landing on exposed food, and more so when they land on the exposed skin of the face, arms, and legs. It is not uncommon for phobias to be manifested in individuals that develop near hysteria or psychosis in the presence of flies that fly about their body and alight on exposed skin.

Diseases Produced by Microorganisms and Helminths

Many of the human diseases vectored by cyclorrhaphous flies are mechanically transmitted pathogens that cause gastrointestinal disorders. Synanthropic species, particularly house flies *(Musca domestica),* are incriminated in contaminating exposed food with the bacteria that cause salmonellosis *(Salmonella)*, shigellosis *(Shigella),* typhoid *(Eberthella),* and cholera *(Vibrio).* On occasion, "pinkeye" inflammation of the eye conjunctiva may be produced by any number of infectious bacteria carried by either house flies or eye gnats in the genus *Hippelates* (family: Chloropidae). A number of viral diseases, including the virus that causes poliomyelitis, are accidentally transmitted to humans by flies acquiring viruses from contaminated garbage, human feces, and sewage. Among the species that may carry polio are the house fly, green bottle fly *(Phaenicia sericata),* and black blow fly *(Phormia regina).*

Fly-associated diseases are not limited to bacteria and viruses, but also include intestinal protozoa and helminths (parasitic worms) carried by house flies that either contact or ingest these parasites while feeding on contaminated feces. The cysts of the protozoans that produce amoebic dysentery *(Entamoeba)* and giardiasis *(Giardia)* normally pass through the intestinal tract of the fly and are deposited on the surface of food as the fly defecates while feeding. The eggs of parasitic worms are capable of being carried either on the legs and mouthparts of house flies or successfully passed through the fly's gut. When food contaminated with worm eggs is ingested, the eggs will hatch and begin the parasitic stage of the worm's life cycle. The house fly has been found carrying the eggs of a variety of parasitic worms represented by a number of forms, including species of *Taenia* and *Ascaris,* and the dog tapeworm *(Dipylidium caninum).*

Myiasis

Higher flies that produce myiasis exhibit different levels of parasitic relationships from species with larvae that are totally dependent (obligatory myiasis) upon feeding on host resources to those that are not dependent (facultative myiasis) and only utilize host resources opportunistically when available. Obligatory myiasis involves species with maggots that either parasitize ("encyst") the skin, exposed wounds, nasal passages, or the gastrointestinal tract. The presence of the maggots and the injury caused by their feeding habits can either result in substantial host tissue degradation associated with "traumatic myiasis" or minimal trauma with no observ-able impact to either the host or its affected tissues. The maggots of species associated with facultative myiasis normally feed on alternative food resources that may include carrion and animal excrement.

Obligatory Myiasis

The most severe forms of traumatic myiasis are obligatory associations that result in significant tissue destruction, loss of host vigor, and occasionally host death. Humans are rarely involved with this form of myiasis, however, many species of wildlife, primarily ungulates, are significantly affected. The open sores of cattle are frequently invaded by the maggots of the primary *(Cochliomyia hominivorax)* and secondary *(Cochliomyia macellaria)* screwworm, and during large outbreaks of screwworm myiasis humans can become involved. Massive infestations by screwworm maggots usually decrease the overall vigor of the affected animal, and severely impacted individuals often succumb. Cattle are affected by another fly, the common cattle grub *(Hypoderma lineatum),* with larvae that hatch from eggs deposited around the feet and migrate to the back where they lodge themselves inside a sacculate "warble." When cattle are being actively parasitized by cattle grubs, they often become terror-stricken and gallop about madly. This behavior, termed "gadding," often quickly spreads throughout an entire herd, which leads to the cattle grub's notoriety as the "gadfly."

Horses are affected by an intestinal bot *(Gasterophilus intestinalis).* The heel fly deposits its eggs around the ankles of its hosts, which are are licked from the ankles as the animal grooms and then hatch when they reach the gut. The young grubs attach themselves to the lining of the stomach, develop to maturity, and detach to be passed in the manure just prior to pupation. Sheep too are affected by still another bot, the sheep botfly *(Oestris ovis)* that attacks the nasal cavity of infested animals. Since the site of the infestation is limited to the head region, species in this group (family Oestridae) are often called "head maggots." Eggs are deposited around the nostrils and upon hatching the young larvae crawl up the nasal passage into the sinuses where they attach, feed, and complete their development. Mature larvae detach, crawl back to the nostrils, and drop to the ground to pupate. Severely infested sheep experience considerable discomfort and often develop a number of associated respiratory disorders related to impaired breathing. There are recorded cases of sheep bots infesting humans, particularly sheep herders that are in constant contact with their flocks. Other species of oestrids are associated with deer and horses. Among the bots are giant blackish and gray flies of the family Cuterebridae that infest rodents, rabbits, and hares. The maggots of *Cuterebra* spp. are huge (1 in. [25 mm] in length; and 1/2 in. [13 mm] in dia.) and encyst either around the neck, belly, or flanks of their host.

Facultative Myiasis

The species of flies involved with facultative myiasis are not obligated to this form of specialized maggot parasitism, but become involved fortuitously when conditions permit. Facultative myiasis is largely limited to cutaneous (skin) and enteric (gastrointestinal) types of infestations. Blow flies (e.g., *Phaenicia)* and flesh flies (e.g., *Sarcophaga* and *Wohlfahrtia)* are frequently associated with open wounds and sores occurring on many different species of vertebrates. Humans are sometimes affected when eggs are deposited at the sites of open sores and the maggots, unknown to the victim, enter the wound to begin feeding. One species, the green bottle fly *(Phaenicia sericata)*, is notorious for its ability to invade and feed on necrotic human tissue. However, the myiasis produced by this invasion is considered beneficial because the maggots actually cleanse the wound and secrete the hormone allantonin that promotes healing. Their use in treating wounds following surgery in field situations has given them the unusual alias as "surgical maggots."

Enteric Myiasis

Enteric myiasis occurs when the maggots of flies are accidentally ingested via contaminated food. The resulting infestation of the gastrointestinal tract produces little discomfort in the host; but when the maggots are passed in the feces, their presence invariably gains considerable attention. Many species of blow flies and perhaps some muscoids and flesh flies have been associated with enteric myiasis, but two species of more primitive flies, the rattail maggot *(Eristalis)* of the family Syrphidae and black garbage fly *(Hermetia illucens)* (refer to previous chapter), often are involved with enteric myiasis in humans. Humans acquire the larvae of these species by consuming either contaminated fruits or vegetables.

FORENSIC SCIENCE AND HIGHER FLIES

The role of synanthropic species in the natural cycle of decomposition of human remains is now being applied by criminologists and forensic scientists in determining the time of death. Once death has occurred, an exposed corpse begins the process of decomposing that may include consumption of the "flesh" and "internal organs" by fly maggots. Controlled experiments using human remains and monitoring decomposition have revealed that a corpse is systematically attacked by different species of flies at different times in the decomposition cycle. Knowledge obtained from these observations, combined with species (maggot) growth rates at different temperatures, now enables forensic specialists to accurately (± one day) determine the time of death. Time of death estimates also are corroborated by the presence of other insects (e.g., carrion, hister, and dermestid beetles) that are equally involved with the decomposition process. Both the larvae and adults of some "forensic" beetles do not consume the remains, but prey upon the maggots of the various species of decomposer flies.

SPECIES OF PUBLIC HEALTH IMPORTANCE

Blood Feeding Species

(Figures 8-2, 8-4)

Stable Fly

The stable fly *(Stomoxys calcitrans)* is a barnyard species commonly associated with stables, corrals, and stockyards. The adult fly (1/4 in.; 8 mm) resembles the house fly, but lacks the pale markings on the sides of

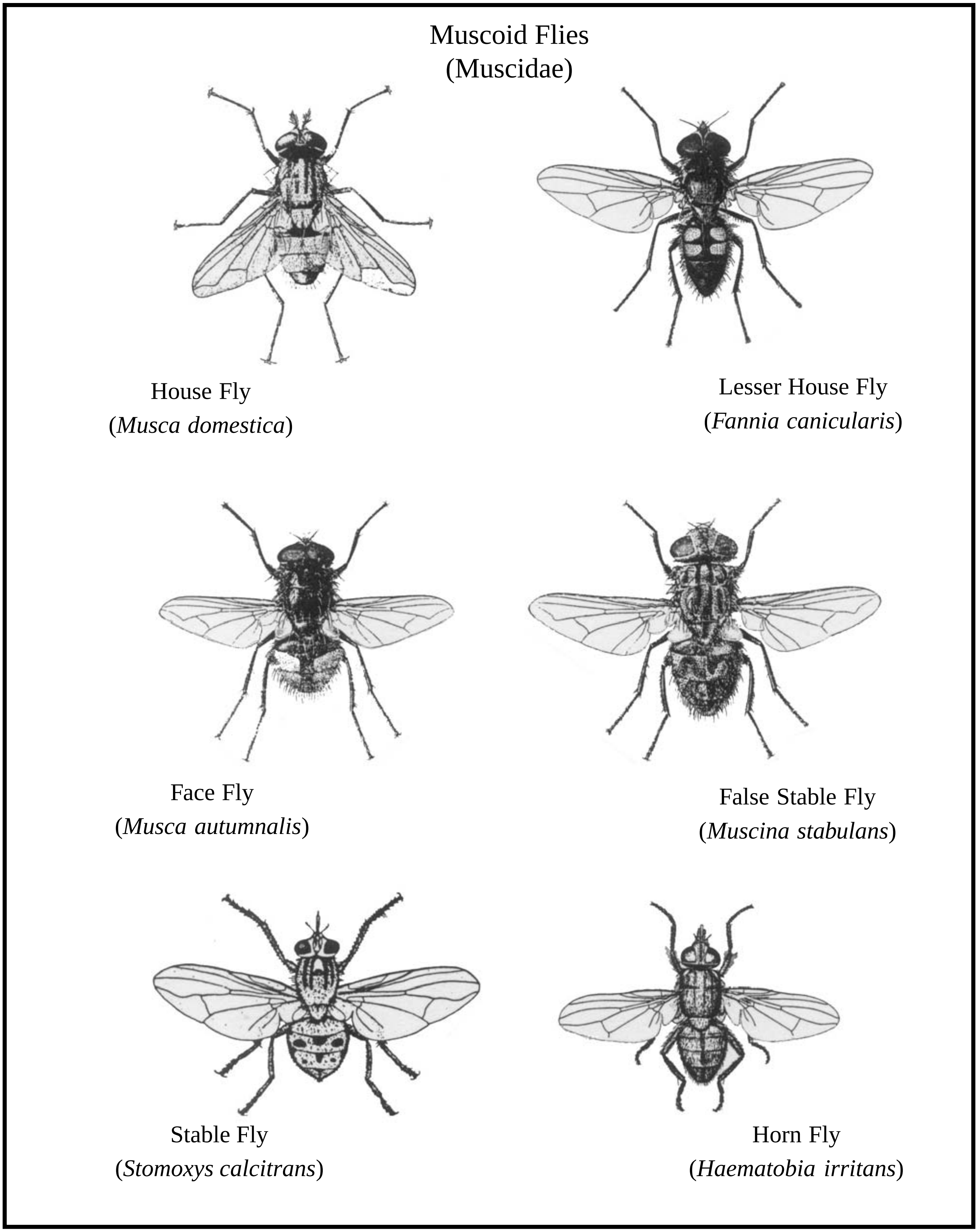

Figure 8-2. Blood-feeding muscoid flies (courtesy U.S.D.A.).

the abdomen. The dorsum (top) of the thorax is marked with four longitudinal stripes and the abdomen is checkered in light and dark grays. Most importantly, this fly has piercing mouthparts as compared to the characteristic sponging-type mouthparts of the house fly. Maggots develop in the moist mixture of straw, hay, and manure that accumulates in stalls and along the margins of corrals and feed lots. Larvae complete their development in 14 to 26 days under optimal temperature and dietary conditions with a pupal period of approximately equal duration. Development from egg to adult can occur in as little as two weeks, but more commonly in three to four weeks. Adult females are painful biters and will attack a variety of hosts, including horses, cattle, domestic pets, and humans. Stable flies are common throughout the United States and widespread in California. Seasonality varies considerably along both climatic and geographical boundaries.

Horn Fly

The horn fly *(Haematobia irritans),* introduced from Europe in 1887, closely resembles the stable fly, but this species is more slender and only half the size (3/16 in.; 4-5 mm). The feeding habits of both flies also differ, with the stable fly facing upwards versus the horn fly facing downward when they feed. Females deposit eggs almost exclusively on the surface of fresh manure pats of range cattle. Eggs hatch in one to two days and the larvae proceed to feed on the dung for a period of four to 12 days depending upon prevailing temperatures. Mature larvae migrate from the moist dung to seek a dry site within the pat to pupate. Pupae emerge in several days. This species typically overwinters in rangeland and pasture habitats as pupae embedded in moist pats. Horn flies are common during the late spring and summer in the Central Valley of California where they are often observed feeding in masses on the flanks, rump, and belly of cattle and horses. Overwhelming infestations can seriously decrease animal vigor and reduce milk production in dairy cattle. Fortunately, this species only occasionally bites humans by accident.

Hippoboscids

The hippoboscids (family: Hippoboscidae, including the “bat flies” Nycteribiidae and Streblidae), which are often called either “ked,” “louse flies,” or “bat flies” because of their superficial resemblance to lice, represent an interesting group of highly specialized ectoparasites of birds, bats, and ungulates. Their flattened bodies and exaggerated leg structure (“crab-shaped”) are particularly adapted for mobility through hair, fur, and feathers. Some species are flightless, while others have wings and are capable of long-range dispersal. Among some of the well-known hippoboscids are the sheep ked *(Melophagus ovinus),* various deer keds *(Lipoptena* spp.), and pigeon fly *(Pseudolynchia canariensis).* Humans are occasionally bitten in woodlands by winged deer keds and by either sheep keds or pigeon flies if involved with raising pigeons or shearing sheep.

SPECIES ASSOCIATED WITH HUMAN ACTIVITY

(Figures 8-2, 8-3, and 8-4)

Eye Gnats

There are a number of eye gnats *(Hippelates* spp.) in the family Chloropidae that occur in California. One particular species, *Hippelates collusor,* is associated with causing considerable annoyance between the months of April and November to residents living in the lower desert regions of southern California. The adults of this small fly (1/16 in.; 2-3 mm) are shiny and variously colored in shades of browns, blacks, and yellows. Their notoriety as “eye gnats” comes from their behavior of swarming about the face and eyes, and landing on the eyelids to feed on lacrimal secretions. This species breeds in decaying vegetable matter and animal products that have been mixed with soil. Eggs deposited in loosely compacted soils hatch in two to four days with complete larval development requiring and additional seven to 12 days. Pupation occurs just below the soil surface with adult emergence in one to two days. The pupa also functions as the overwintering stage for this species throughout much of its range.

Muscoid Flies

The species comprising this family (Muscidae) of synanthropic flies include some of the most notorious forms known to plague human society. Among the notable species are the house fly *(Musca domestica),* lesser house flies *(Fannia* spp.), false stable fly *(Muscina stabulans),* and face fly *(Musca autumnalis).* All of these species are similar in appearance and breed in domestic situations. Their respective life histories also are remarkably similar with the exception of some slight differences in larval nutritional requirements, seasonality, dispersiveness, behavior, and associated disease relationships.

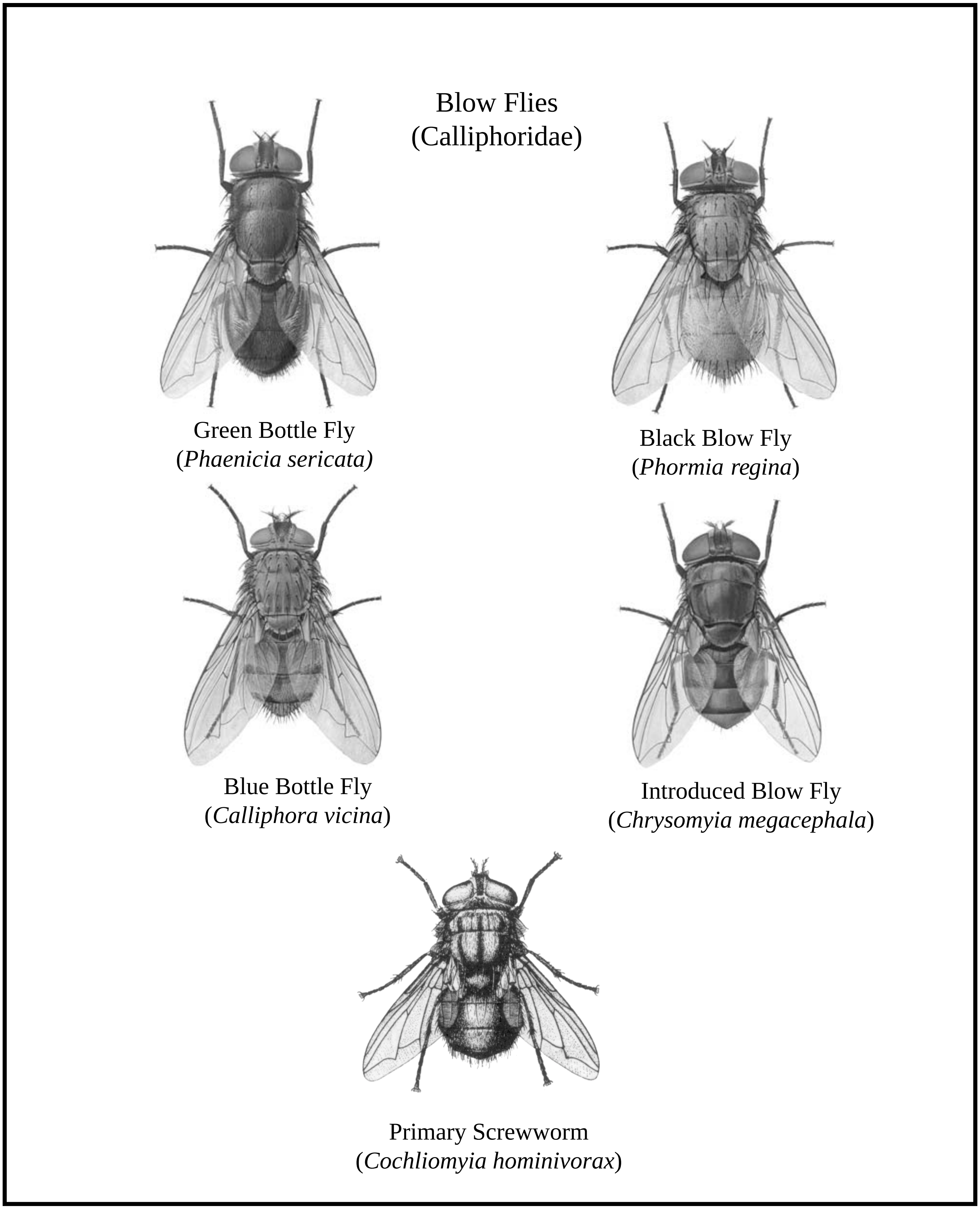

Figure 8-3. Blow Flies associated with human activity (courtesy Greenberg, Flies and Disease Vol. 1, and U.S.D.A.).

House Fly

Other than mosquitoes, the house fly *(Musca domestica)* is perhaps the singular most nemesis of humans worldwide. This fly occurs on every continent and is capable of explosive reproduction when provided the opportunity to breed unabated. Literally millions of house flies can be produced in days in poorly maintained landfill sites, discarded piles of rotting fruits and vegetables, and exposed animal wastes (e.g., guano, fecal material, droppings, etc.). The adults (l/4 in.; 8 mm) are colored dark gray with four dark longitudinal stripes on the dorsum of the thorax and the abdomen is conspicuously marked with lateral "crescent-shaped" pale areas. Females deposit their eggs on the moist surface of larval food sources and hatch in eight to 12 hours. The newly hatched larvae begin feeding and complete their development in five to eight days. Mature larvae will usually disperse from their feeding sites, or sometimes remain sedentary to pupate in a protected location. Adult emergence normally occurs five days after pupation. The minimal time required for the production of a single generation of house flies has been at four days. Adult house flies cease activity in the fall and seek protective overwintering sites where they may remain dormant for periods of exceeding one to two months or longer.

Lesser House Flies

More localized than the house fly, the smaller (3/16 in.; 4 mm) lesser house flies *(Fannia* spp.) are common seasonal pests with larvae possessing unique lateral processes. These flies breed predominately in moist accumulations of decaying vegetable matter, bird droppings, and animal droppings/manure. The adults look much like house flies except the abdomen is narrower and the thorax has three compared to four brownish longitudinal dark stripes. The adults also behave differently because instead of flying about in the open as house flies commonly do, lesser house flies aggregate in swarms in the shaded spaces on porches, walkways, patios, and beneath the overhanging limbs of shade trees. Their identity is further revealed by a peculiar habit of flying at eye level in either an irregular or abrupt back-and-forth elliptical pattern. Females deposit their eggs on the moist surfaces of the larval food source and hatch within a day. Larvae feed continuously and reach maturity within a period of one to three weeks. Pupation typically occurs within the food source and most adults emerge in one week. Seasonally, *Fannia* populations in California are most abundant during the spring and early summer. Overwintering is accomplished either by dormant adults or slowly developing larvae that feed throughout the winter in warmer parts of its range. Our most common and widespread species is the lesser house fly *(Fannia canicularis),* followed by a variety of subordinate species, including *Fannia scapularis, Fannia femoralis,* and *Fannia benjamini.* Of these species, the canyon fly *(F. benjamini)* is suspected in transmitting the eyeworm (nematode *Thelazia californiensis)* to humans in southern California.

False Stable Fly

The false stable fly *(Muscina stabulans)* is similar in appearance to the house fly, but it is slightly larger (3/8 in.; 9 mm), the blackish abdomen lacks the prominent lateral pale areas, and the proboscis (sponging-type) is not visible from above. Eggs are deposited on the moist surface of decaying vegetable matter and cow dung. Hatching occurs in two to three days, and subsequent larval development takes anywhere from ten days to upwards of almost four weeks depending upon temperature. Mature larvae disperse from their food source to seek a sheltered site in which to pupate. The pupal period is six to ten days. Like house flies, adults are capable of long-range dispersal and at times can become quite annoying to residents living near dairies and stables. Adults overwinter either singly or in small groups that aggregate in woodpiles, outbuildings, and sometimes in the attics of houses.

Face Fly

The face fly *(Musca autumnalis),* introduced into North America from Europe in the 1950s, is another species that is often mistaken for the house fly. This species, like the false stable fly, is larger (3/8 in.; 9 mm) with a uniformly dark abdomen in the female. The abdomen of the male is ornamented with reddish versus yellowish lateral patches. Females deposit eggs just below the surface of fresh cow pats. Eggs generally hatch in about 24 hours, and the newly hatched larvae begin feeding and rapidly mature in three to four days. Pupation occurs either within drier portions of a manure pat, or mature larvae will disperse to pupate in the nearby soil. Adults emerge after a pupation period of seven to ten days.

Face flies, as their common name indicates, characteristically aggregate on the face of horses and cattle where they readily feed on the lacrimal secretions associated with the eyes. Their eye-feeding habits are often responsible for the rapid spread of bovine keratitis, or "pinkeye" *(Moraxella bovis)*, within an affected cattle herd. Cattle ranching operations in the Central Valley of California are prone to "pinkeye" epidemics that can seriously affect herds grazing along the foothills of the Sierra Nevada and Coast Ranges.

Calliphorid or Blow Flies

This is another diverse group of flies in the family Calliphoridae that are known colloquially as "blow flies" by the carrion feeding habits of the larvae or "maggots." Most species are colored with metallic blues, greens, and coppers, while others are more drab in appearance being either dark brown to gray or submetallic (e.g., dark blue to black species).

Green Bottle Fly

The green bottle fly *(Phaenicia sericata)* is perhaps the most well-known and widely distributed blow fly in California and elsewhere in North America. The metallic green to slightly bronzy adults (3/8 in.; 8 mm) are found throughout the state from sea level to over 8,000 feet in the Sierras and Cascades. Females lay their eggs on the moist surfaces and crevices of rotting vegetable matter, carrion, animal excrement; and on rare occasions in the open wounds of animals, including humans. Hatching occurs in less than one day and under optimal conditions the larvae reach maturity within three to four days. Mature larvae characteristically disperse from their food source to pupate if not confined by the sides of garbage receptacles and other containers. Adults emerge in about seven to ten days. This species, which overwinters as pupae, is active year-round in warmer regions of the state with populations reaching peak numbers during the summer months.

Black Blow Fly

The black blow fly *(Phormia regina)* is related to the green bottle fly, but unlike the previous species, this blow fly is more abundant during the cooler months of the year, particularly during late winter and spring. The adults (3/8 in.; 8 mm) are colored a deep metallic blue to almost black, and the thorax bears faint dark longitudinal stripes that often blend with age. Unlike other common calliphorids, the adults of this species rest with their wings folded "parallel" over the top of the abdomen and not in the typical inverted "V-shaped" configuration. Larval food requirements are similar to the green bottle fly with the exception that this species breeds predominately in carrion and to a lesser extent in animal excrement and rotting vegetable matter. The life cycle is longer than most other blow flies since development occurs during cooler late winter and early spring temperatures. Under normal spring conditions, the time from egg to adult requires from four to eight weeks.

Common Blow Fly

The common blow fly *(Calliphora vicina)* is another ubiquitous species found throughout California, along with a closely related species *(Calliphora lilaea)* that is more common in the southern part of the state. The adults (3/8 in.; 9 mm) are similar in appearance to the black blow fly, however, the coloration is more blue-gray with the thorax becoming almost blackish. The wings are held in an inverted "V-shaped" configuration rather than folded parallel over the top of the abdomen. This species, unlike the black blow fly, is more commonly active during the warmer months of the year, however, they are known to produce "indoor" winter broods from dead rodents. Compared to the other blow flies discussed herein, this species breeds almost exclusively in carrion, particularly in the carcasses of commensal rodents (e.g., roof rats [*Rattus rattus*] and house mice [*Mus musculus*]). It is not uncommon for the carcasses of rats and mice poisoned indoors to produce several hundred or more adults that appear suddenly from the attic or wall voids through vents, light fixtures, and electrical outlets. Eggs are deposited on a fresh carcass and hatch within one to two days. Larvae begin feeding immediately consuming the head, viscera, and muscle tissue and completely "blow" a carcass in about three to nine days. Mature larvae invariably disperse outward from the carcass to seek safe shelter in which to pupate. Adult emergence occurs in approximately four to seven days depending upon temperature.

Imported Blow Fly ("Latrine Fly")

This distinctive blow fly *(Chrysomyia megacephala)* (3/8 in.; 9 mm) colored bronzy-green with an exaggerated large head and compound eyes was introduced into the United States (Los Angeles area) from the Orient in the 1980s. Compared to the green bottle fly, this species is slightly more robust and proportionately shorter giving it a "barrel-shaped" appearance. The larvae breed in carrion, garbage, open privies, improperly discarded disposable diapers, and occasionally in the open wounds of domestic pets. Seasonally, adults are active during the warm summer months in the Los Angeles Basin and population abundances peak sometime in August and September. Eggs deposited on suitable food resources hatch in one to two days. Larval development occurs in less than one week with the pupal period requiring perhaps an additional week until emergence. The adults have a peculiar habit of "perching" near breeding sites.

Red-Tailed Flesh Fly

The red-tailed flesh fly *(Sarcophaga haemorrhoidalis)* is a large species (3/4 in.; 20 mm) distinctively marked in grays and blacks with three black stripes on the thorax and a contrasting checkered pattern on the abdomen. The terminal segment of the abdomen is colored bright red. Like other flesh flies in the family Sarcophagidae, this species may rarely larviposit in open animal wounds (facultative cutaneous myiasis), but more often in either animal excrement or carrion of dead animal carcasses, including garden snails. Females do not lay eggs, but deposit live larvae that quickly enter their food resource to feed. Compared to other flies, larval development is extremely rapid, requiring only three days to complete under optimal conditions. Mature larvae egress from their feeding sites and seek protective shelter in which to pupate. The pupal period lasts approximately eight to ten days. The red-tailed flesh fly is found throughout California with abundance increasing at lower elevations exclusive of the deserts.

SPECIES CAUSING MYIASIS

(Figures 8-3, 8-4, and 8-5)

Rat-Tailed Maggot

This well known species *(Eristalis tenax)*, also known as the "drone fly," is easily recognized by its close resemblance to honeybees and distinctive hovering behavior (typical of flies in the family Syrphidae) around flowers in urban and rural backyards. The adults (5/8 in.; 18 mm) of this species differ from bees by the two wings, lack of body hairs, and amber colored spots in the middle section of the wings. The eggs are deposited on the surface of liquid manure and other wet situations with a high organic content. Larvae hatch and feed on organic nutrients, and in the process they often aggregate in seething masses on the surface of the water. The name, rat-tail maggot, comes from the fact that the larva bears an extremely elongate breathing tube or siphon, which can be extended over two inches to reach the surface of the water. Humans are accidentally parasitized when either rotten fruit or foul water containing larvae is ingested. In rare cases, where living conditions are deplorable, the larva actually enters through the rectum. Since rat-tailed maggots do not require "host-type" resources, the form of myiasis caused by this species is referred to as "pseudomyiasis" (pseudo = false).

Screwworm Flies

Both the primary screwworm *(Cochliomyia hominivorax)* and secondary screwworm *(Cochliomyia macellaria)* are notable species of blow flies (family: Calliphoridae), with larvae that produce trauma as a consequence of feeding in the open sores and wounds of mammals, primarily ungulates, and on rare occasions humans. The larval development of the primary screwworm occurs exclusively in either live or necrotic animal tissue, while the larvae of the secondary screwworm can utilize carrion if available. The adults (1/4 in.; 8 mm) of both species are similar with an overall metallic blue-green coloration, and the thorax bears three distinct longitudinal black stripes. Historically, both species have severely impacted range cattle in the western United States. Dehorning practices, combined with barbed wire, resulted in creating open wounds that were invaded by the larvae of screwworms. Today, the trauma caused by screwworm flies is being successfully managed by more attentive sanitary and veterinary practices.

Female screwworm flies deposit eggs around the periphery of an open wound. Eggs hatch in approximately 10 to 22 hours and the larvae immediately begin feeding on the lymphatic excretions, blood, and exposed tissue. Larvae develop to maturity in approximately four days (range of 3-5 days), exit the wound, drop to the ground, pupate, and emerge in approximately one week.

Botflies

The botflies are represented by a group of species belonging to a number of specialized families that share a common biological necessity of being obligatory parasites of either the skin (cutaneous myiasis) or gastrointestinal tract (enteric myiasis) of their hosts.

Common Horse Botfly

The horse bot *(Gasterophilus intestinalis)* is an

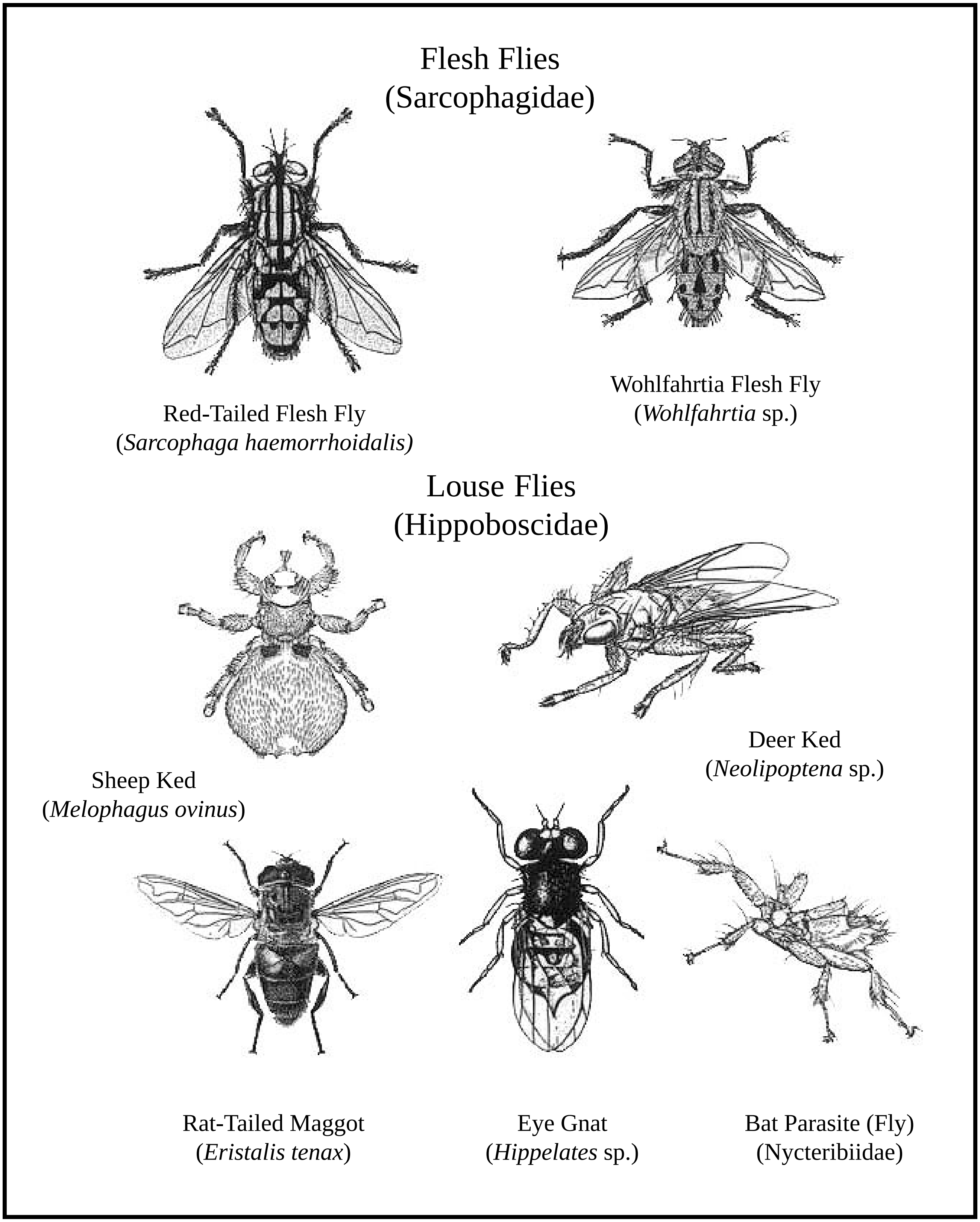

Figure 8-4. Flies associated with human activity (courtesy U.S.D.A. and *Manual of Nearctic Diptera*, Monograph No. 28, Agriculture Canada, 1981).

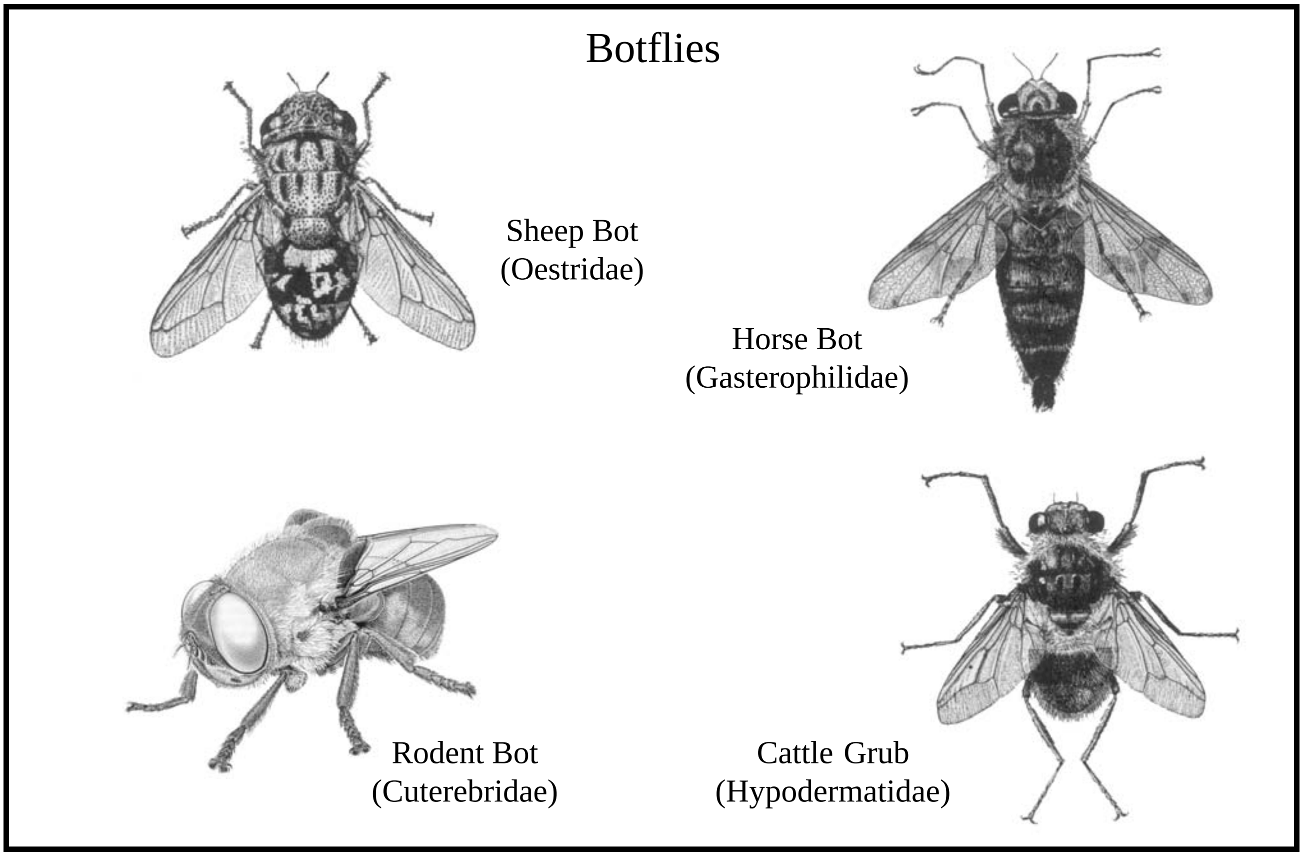

Figure 8-5. Higher flies causing myiasis (courtesy U.S.D.A. and *Manual of Nearctic Diptera*, Monograph No. 28, Agriculture Canada, 1981).

intestinal parasite of equines that belongs to the family Gasterophilidae. The hairy adults (1/2 in.; 12 mm) resemble honeybees with contrasting colors of reds, grays, and browns. This species is active during the summer, and the larvae persist through the winter attached to the esophageal portion of the stomach. During the spring, the larvae detach and are voided to pupate in the ground.

Cattle Grub

This common cutaneous parasite *(Hypoderma bovis)* of cattle belonging to the family Hypodermatidae resembles a small (1/2 in.; 15 mm) bumblebee with four prominent polished lines on the dorsum of the thorax. Larvae hatch from eggs deposited on the legs, bore directly beneath the hide, and migrate internally to the back where they encyst to form raised "warbles" (tumors). For a period of eight to 12 weeks, larvae remain within this cyst through the latter part of fall and winter. By springtime, the larvae exit the warbles and fall to the ground to pupate. Adults emerge four to five weeks later. The entire life cycle requires approximately one year to complete.

Sheep Botfly

The sheep bot *(Oestris ovis)* is a remarkable fly with parasitic larvae or "head maggots" that develop in the nasal cavities/sinuses of sheep and goats. Other species in this family (Oestridae) infest the nasal passages of deer, and like the previous species, occasionally humans. An occasional accidental infestation of head maggots in humans produces a condition known as "ophthalmomyiasis."

The adult fly (1/2 in.; 14 mm) is colored in yellows, browns, with a variegated gray and brown abdomen. The female deposits live larvae on the nostrils of the host in the fall, from where they migrate to the sinuses, and attach to complete their development. The maggots reach maturity in the spring, at which time they detach, exit through the nostrils, and drop to the ground to pupate in the soil. Adult emergence occurs in three to six weeks, depending upon local conditions and temperature.

Rodent and Rabbit Bots

These giant (1 in.; 25 mm), flies in the genus *Cuterebra* are typically colored black with the abdomen variegated in grays, blacks, and whites. Eggs are not deposited directly on the host, but in the burrows of the rodent and lagomorph (hares/rabbits) hosts. Newly hatched larvae either seek or by chance contact their host. Once on the host, larvae quickly bore into the skin and encyst at that site for the remainder of their development. Mature larvae detach to pupate either in the soil or sheltered ground site. The life cycle of most *Cuterebra* species is completed in one year.

MANAGEMENT AND CONTROL

Overview of Integrated Pest Management (IPM) Strategies in Fly Control

The explosive reproductive potential of cyclorrhaphous flies and their ability to disperse makes these vectors difficult to control. The application of chemical sprays using various insecticides usually will yield only partial success in attempts to rapidly suppress a developing fly problem. Effective and lasting control requires the implementation of IPM that includes a more comprehensive array of methodologies designed to produce both immediate, short term, and sustained population management. Balanced IPM fly programs include all or a custom combination of the following control elements: 1) source reduction; 2) exclusion; 3) biological control; 4) chemical control (includes chemoprophylaxis); and 5) public education.

Source Reduction

The best overall method of fly control is to either prevent or significantly reduce access to larval breeding resources. This critical element of IPM is classically referred to as source reduction. All successful fly management programs implement some form of non-chemical control options that require eliminating food sources to both adults and primarily larvae. Reduction of adult resources is often next to impossible in most situations leaving the only remaining alternative of denying flies access to larval food sources, such as garbage, carrion, decaying vegetable matter (agricultural wastes), and manure. In the absence of suitable larval control, the successes anticipated for a comprehensive fly management program will never become an operational reality. The following four sections detail some practical procedures and cultural practices that have been proven successful in significantly reducing fly production when properly applied.

Carrion

A variety of synanthropic species breed in the decaying carcasses of dead animals. Timely cremation and disposal or burial of dead animal remains in both rural and urban situations denies breeding to both blow flies (e.g., *Phormia*, *Phaenicia*, and *Calliphora)* and flesh flies (e.g., *Sarcophaga).*

Garbage

Garbage represents a major breeding source for a number of well-known species, including the house fly (*Musca domestica*), green bottle fly (*Phaenicia sericata*), and occasionally lesser house flies (*Fannia* spp.). The rapid rate at which these species can complete their development in garbage requires biweekly pickup during the summer months and perhaps removal only once every two weeks during the winter in frost-free areas. Similarly, sanitary landfill management for fly control requires that daily grading layers of refuse be covered with at least six inches of compacted soil to keep flies from ovipositing on moist decaying organic materials contained within the refuse.

Manure and Animal Droppings

Flies are notorious for their breeding associations with animal droppings and manure. Pet droppings in backyards and accumulations of bird droppings (e.g., domestic pigeons) on the roofs of commercial buildings are the sources of breeding for house flies *(Musca domestica),* some blow flies (e.g., *Phaenicia),* and lesser house flies *(Fannia* spp.), particularly *F. canicularis.* The recently introduced "latrine fly" *(Chrysomyia megacephala)* breeds in the fecal waste accumulations in disposable diapers that are left uncovered outdoors for several weeks. Local infestations of this fly are easily controlled by the weekly removal of disposable diapers. Manure accumulations at horse stables, dairies, feed lots, and rural pastures characteristically produce house flies, stable flies *(Stomoxys calcitrans),* false stable flies *(Muscina stabulans),* face flies *(Musca autumnalis),* and horn flies *(Haematobia irritans)*. Routine removal, rapid drying, and "wind row" composting of manure by-products significantly reduces the suitability of these otherwise productive breeding substrates. There are various alternative composting techniques that involve blending and curing procedures that produce a similar result in reducing breeding suitability.

Decaying Vegetable Matter

Decaying vegetable matter that includes grass clippings, culled fruits and vegetables, spoiled silage, and nut husks represent a major source of house flies and rarely some species of blow flies (e.g., *Phaenicia)*. Populations of house flies can proliferate quickly during the summer months when breeding goes unchecked in agricultural refuse and poorly managed composting operations. Within a span of several weeks at optimal developmental temperatures, house fly breeding in decaying fruits (e.g., tomato culls) literally explodes with the production of millions of adults that eventually disperse to invade adjacent residential areas and parklands. Therefore, prevention of such outbreaks requires either deep burial, tilling, or rapid drying of fruit and vegetable culls.

Environmental Modification (EM)

This element of IPM requires an in-depth ecological understanding of the environmental parameters that affect fly biology and reproduction. This understanding becomes evident because what flies require from "nature" may be physically altered in a manner that preempts exploitation by either larvae or adults. Unfortunately, successful application of EM in fly management programs has yet to be pursued economically because alternative control methods are much easier to implement at acceptable costs.

Exclusion

Fly exclusion has long been practiced to keep flies from entering homes and food establishments where they can become a nuisance to residents and patrons. A combination of screening, fans, sticky traps, and chemical lure traps have been used with some success in preventing flies from entering where they are not wanted. Of the above exclusionary methods, screening is perhaps the best barrier against flies gaining access to the inside of structures. Outdoors, traps that either capture (e.g., chemical type) or entangle (e.g., sticky tape/strip traps) adults can be effective if properly placed.

Biological Control (BC)

Synanthropic flies have a variety of natural predators that consume either larvae or maggots. However, their intended use is limited to special situations where fly breeding occurs in managed environments associated with chicken ranches, hen houses, and other poultry operations. Manure produced by birds suspended in cages is deliberately allowed to "cone" beneath individual cages. The cone pile of manure affords predators optimal access to prey upon any fly eggs, larvae, and pupae that may be present. Among the more common predators of flies (e.g., *Musca domestica)* present in coning operations are species of mites and parasitic wasps (Hymenoptera: Chalcidoidea) that feed on the eggs; hister beetles (family Histeridae) and ants (family Formicidae) that prey upon larvae; and parasitic wasps (e.g., family Chalcidae) with larvae that feed on the internal tissues of pupae. Poultry manure that is properly coned and supplied with fly predators and parasites rarely requires applications of insecticides to manage either house or lesser house fly infestations. There is a myriad of fly predators in nature, however, their role in fly IPM is not practical as a consequence of difficulties in mass rearing and effective application.

The release of laboratory colonized sterile males to control screwworm flies (*Cochliomyia* spp.) in the southwest provided some effective level of control during recent screwworm outbreaks. The strategy of sterile male releases, involving massive numbers, is intended to numerically overwhelm the mating capacity of wild males. Wild females having mated predominately with the released sterile males would deposit uninseminated (nonviable) eggs that fail to develop (embryonate). Over time and with predominately sterile male matings, a screwworm outbreak would be progressively suppressed but not totally eliminated. Sterile males currently are being used in an attempt to control the Mediterranean fruit fly (*Ceratitis capitata*) in southern California. The application of sterile male control strategies in fly management is not promising because of the expense and logistics involved with developing an economically feasible program that includes the costly production and distribution of the sterile males.

Chemical Control

Chemical control strategies are the most commonly applied in suppressing fly infestations and preventing adult flies from contacting humans and domestic animals. The types of chemicals used in fly control can be subdivided into those that kill by disrupting nerve actions and those that kill by preventing the transformation of pupae to adults. Neurotoxic compounds include a dwindling number of currently available products, while insect growth regulators (IGRs) are limited to various formulations of methoprene. Chemicals used to kill larvae are applied as either oil base, aqueous, wettable powder, or liquid concentrates of the product. Adulticides are applied similarly with the exception that adult control often requires ultra low volume (ULV) and fogging to kill adults in flight or resting "en masse" on manure and rotten vegetable piles. When IGRs are applied, knockdown does not occur but is "realized" when the pupae fail to emerge.

Public Education

Excluding agricultural and commercial sources of flies and the occurrence of fly breeding in residential settings accounts for a majority of citizen complaints received by local vector control and other health agencies. This situation certainly qualifies for instituting public education techniques to increase both resident awareness of what conditions breed flies and what actions they can take to effectively reduce fly breeding on their property. A simple routine of removing pet droppings daily, properly composting grass clippings and other landscape prunings, and accommodating weekly garbage (deposited in plastic bags) pickup has been shown to reduce residential fly breeding by as much as 90 percent. A number of vector control agencies actively pursue public education options and have incorporated sections on fly control in printed materials (e.g., fliers and informational pamphlets) and programs (e.g., oral presentations) presented to schools and interested civic groups.

SURVEILLANCE AND INSPECTION PROCEDURES

Before control procedures are initiated, a fly infestation and associated health problems may require quantification as a determining factor in the selection of management options available to the control technician. Few verses high maggot/adult numbers (indication of population size) may require a casual versus aggressive application of control methods to affect knockdown. Included here is a brief overview of surveillance techniques used to assess the numerical aspects of larval and adult fly infestations, plus a few tips on locating a fly infestation.

Larvae/Maggots

Substrates that produce maggots are inspected for the existence of breeding that is evident by the presence of maggots. Manure, compost, and garbage are routinely examined and sampled by removing either a specific volume or weight of the infested substrate to provide a quantifiable estimate of the number of maggots per square meter (sq. ft.) and/or kilogram (lbs.) of substrate. Volume and weight samples normally are bagged in plastic and returned to a laboratory facility for further processing. Many samples are run through a Berlese funnel that consists of a cone-shaped pan with an internal screened shelf heated by an overhead incandescent light bulb mounted inside the lid. A glass collection jar filled with an alcohol (70%) preservative is attached to the bottom. When the sample is placed on the screened shelf and illuminated, the heat produced by the bulb forces the maggots downward through the substrate, through the screen, and onto the sides of the funnel from where they slide into the jar containing the preservative. Once preserved, the maggots are counted and identified to species. If a Berlese funnel is not available, then the sample must be painstakingly sieved by hand and the maggots counted and identified.

Adults

Quantifying adult fly populations in the field requires a number of elaborate procedures that incorporate various attractant-type traps. Among the more popular baited (chemical lure) adult traps are the one gallon glass fly jar fitted with a specially designed ventilated cone access lid, economical plastic bag trap similar in design to the gallon jar trap, and impregnated sticky strips. Baited traps placed strategically at an infestation site can yield good abundance data over time and space. When placed at sites where there is an abundant adult population, these traps often become literally filled with the bodies of flies trapped within a span of one to two days. Baited sticky-strip traps likewise become saturated with the accumulating bodies of flies that quickly cover the entire surface of both the front and back panels. It is not too uncommon for fly traps to require regular servicing several times a week in highly infested situations.

Besides chemical lure-type traps, flies are visually attracted to light colored surfaces, particularly anything that is painted white. This attribute of their behavior has been used in developing successful visual traps for monitoring landing rates on either a rectangular, square, or lattice surface (e.g., Scudder grill). Abundance is scored as the number of flies present on the landing surface (some traps have grid lines to facilitate counting or subsampling) after a pre-determined time interval (e.g., 15, 30, 40, 60 min., etc.). Since many vector control agencies use light colored vehicles, crude population estimates are often made by taking either a door, fender, or hood count.

LOCATING A FLY INFESTATION

The methods or assortment of methods used by vector control technicians to locate a fly infestation involve the classical process of elimination, which excludes all forms of evidence that do not conform to establishing the fact, "why the flies are here." The inspection process on-site begins by obtaining a general overview of the situation and then proceeding with a systematic search for "clues" associated with an infestation. When the inspection begins, the first priority is to establish what species of fly or flies are creating the problem. Solving that initial question then provides the technician with options that exclude the necessity of conducting wasteful searches of sources that do not support the breeding of the targeted species. Instead, valuable time can be channeled into locating likely sources that do support the production of the targeted species. Locating breeding sources of house flies, blow flies, and flesh flies often requires different search strategies because each of these groups of flies breed in slightly different situations. House fly breeding is commonly associated with composting, bird droppings, and accumulations of organics in trash receptacles (e.g., garbage cans and commercial trash containers). By comparison, blow fly maggots are more likely encountered in decaying animal carcasses, poorly managed composting (liquid digestion accumulations), and excrement. Flesh flies similarly breed in decaying animal carcasses, but the maggots also will take advantage by consuming the remains of dead snails, grasshoppers, and other large terrestrial invertebrates. Lesser house fly production is largely restricted to accumulations of bird guano (e.g., pigeon), rabbit pellets, and occasionally horse, sheep, goat, and cattle manures.

Notes

CHAPTER 9

FLEAS

James D. Lang

INTRODUCTION

Adult fleas are bloodsucking ectoparasites of birds and mammals. Adults vary in size from 0.8 to 8.0 mm in length, depending on the species, are hard-bodied, usually brownish in color, lack wings, and have long legs for jumping. Their mouthparts are used for piercing skin and sucking blood. Adults have antennae, which are short and lie in lateral grooves on the head. Adult fleas are distinguished from other insects by having laterally flattened bodies and backward projecting bristles and spines, which enable them to easily move through the feathers or hairs of their host. These structures also are used to help fleas cling to their host.

DISTRIBUTION

Fleas occur on every continent, including both polar regions, although most are found in the North Temperate Zone. They primarily occur on mammals (95%) which utilize fairly permanent nests or dens, such as rodents and lagomorphs, but also occur on other mammals, such as insectivores, bats, and carnivores. They rarely infest mammals which do not build nests, such as ungulates and marine mammals. They also can be found on birds which mostly nest on or near the ground or in burrows.

BIONOMICS

Most species of fleas usually feed on a single host species, while a few may feed on various hosts. Adult fleas locate their hosts by specialized sense organs (sensillae) located on their antennae and bristles. Some of these sensillae are sensitive to either heat, vibrations, air currents, or the presence of carbon dioxide gas exhaled by the host. A flea can jump vertically and horizontally 150 times its own length.

Fleas may be categorized based on their behavior and host preference. For example, fur fleas have well-developed eyes and are usually as abundant in the nest as on the host, while nest fleas have poorly developed eyes or no eyes and are more common in the nest than on the host. Fleas may be given general names for their hosts, such as being called human, domestic, or sylvatic fleas, or given more specific names, such as the cat flea, *Ctenocephalides felis*, or the European rabbit flea, *Spilopsyllus cuniculi*.

LIFE CYCLE
(Figure 9-1)

Fleas exhibit complete metamorphosis which consists of the egg, larval, pupal, and adult stages. The life cycle of fleas can take as little as two to three weeks, depending on the species, food, and climatic factors. Fleas characteristically leave the host to deposit their usually whitish eggs in the host's nest or sleeping site. Eggs are sometimes laid on the host but will eventually fall off and develop on the ground or in the nest.

The eggs hatch in 2 to 14 days into tiny, whitish, wormlike larvae which are sparsely covered with bristly hairs, have brownish heads, and have a pair of small hooks on the last body segment. Larvae feed on organic debris, on their own skin casts, or on the feces of adult fleas in the nest. A larva goes through three instars which can take a week to several months, then spins a silken cocoon in which it molts into the pupal stage. Particles of dirt often will adhere to the surface of the cocoon.

The pupal stage normally takes a week or two, but can last as long as a year, depending on the species and climatic conditions. Adults usually are ready to feed after 24 hours following emergence from the cocoon. They can survive up to a month without a

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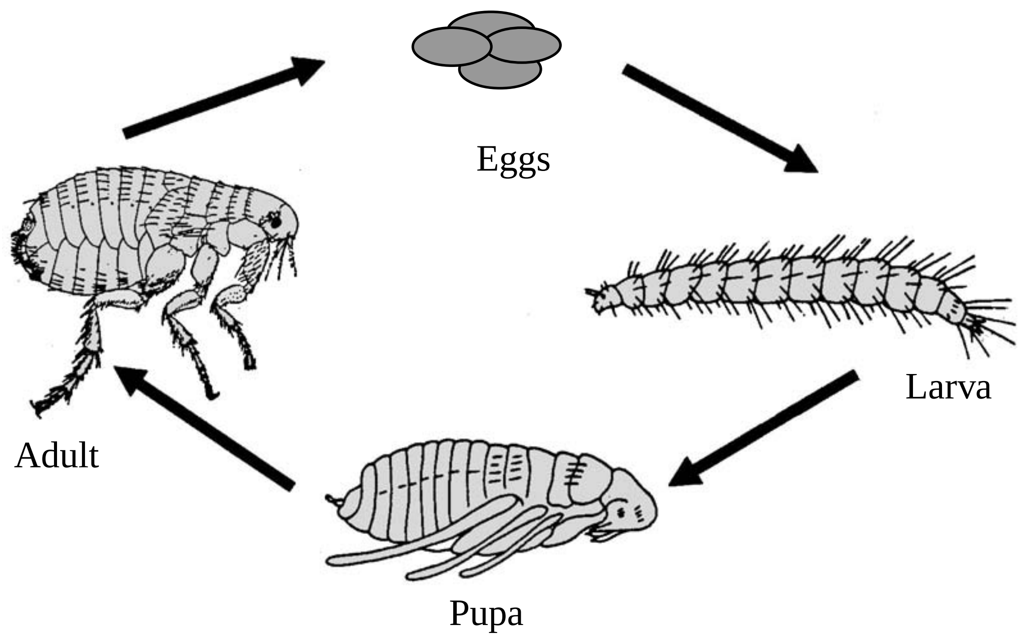

Figure 9-1. Generalized flea life cycle.

blood meal. Both adult males and females feed on blood. Blood ingested by the female flea is needed as a source of "yolk" protein in order to produce mature eggs. Mating usually follows the initial blood meal. The life span of adult fleas ranges from a few weeks to a year or longer.

PUBLIC HEALTH IMPORTANCE
(Figure 9-2)

Fleas can be a public health concern by being nuisances as well as vectors. Their attacks on humans and domestic animals can cause irritation, loss of blood, and severe discomfort, while some individuals may suffer severe allergic reactions or secondary infections from their bites. They can vector disease organisms, which cause bubonic plague, murine typhus (endemic or flea-borne typhus), myxomatosis, trypanosomiasis, and possibly other diseases. Fleas also serve as intermediate hosts for tapeworms and filarial worms. Some of the more important species of fleas of public health significance are discussed below.

Both the cat flea, *Ctenocephalides felis*, and the dog flea, *Ctenocephalides canis*, are cosmopolitan to include the United States, but are less common in the Rocky Mountain states. *Ctenocephalides felis* is more common in the western states. In California, both are more abundant during the summer and in the more humid coastal areas than in the arid ones. *Ctenocephalides felis* can be distinguished from *C. canis* by the former usually having the first two anterior spines of the genal comb being about equal in length to the other spines of this comb. Also, the head of *C. felis* is about twice as long as wide, while that of *C. canis* is about as long as wide. Although both cat and dog fleas can be found in and around homes, *C. felis* is usually the most abundant and more generally distributed on both cats and dogs than *C. canis*. The cat flea is not host specific and will try to feed on almost any warm-blooded animal. Besides domestic dogs, the dog flea also occurs on sylvatic carnivores. They can be serious pests of humans with bites usually occurring on the ankles or legs. Cat and dog fleas are mostly found in a pet's bedding but also can become established in lawns of heavily infested homes so that an infested animal can carry fleas to uninfested

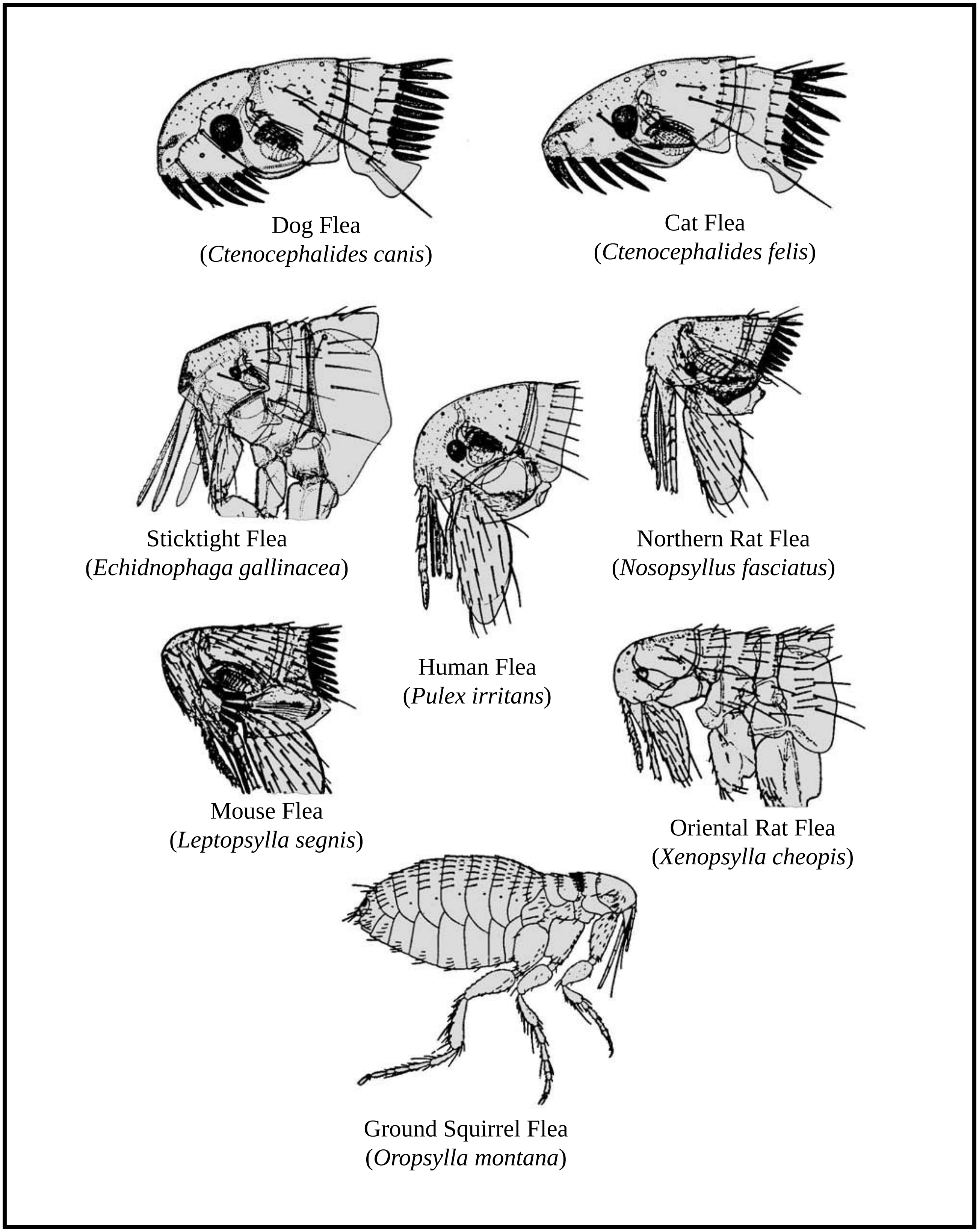

Figure 9-2. Common California fleas (Siphonaptera) (courtesy Pictorial Keys, CDC, 1966, and U.S.D.A.).

premises. Such infestations can be prevented by the exclusion or proper management of cats and dogs. Outbreaks of human cases of murine typhus have been associated with *C. felis* and its hosts to include domestic cats, *Rattus* spp., and opossums. *Ctenocephalides felis* also has been shown to be an intermediate host for the dog tapeworm, *Dipylidium caninum*, and the common rodent tapeworm, *Hymenolepis diminuta*, both of which occasionally attack humans, particularly young children.

The human flea, *Pulex irritans*, can be distinguished from the other common fleas given here by the absence of both genal and pronotal combs, and by having the ocular bristle located below the eye. *Pulex irritans* is found throughout the warmer parts of the world. Besides humans, it also infests domestic animals, particularly pigs, and probably is the most important species occurring in farming areas. It also infests large carnivores. Human infestations by this flea are not as common as those by cat or dog fleas. Human fleas hide in bedding and upholstered furniture. Bites from *P. irritans* are usually distributed over a person's body and are often responsible for an allergic dermatitis. A closely related species, *Pulex simulans*, occurs in the central and southwestern United States and in Central and South America. This flea infests colonial rodents, carnivores, deer, burrowing owls, and a number of other hosts. *Pulex irritans* has not shown to be an important vector for plague or other disease agents, whereas, *P. simulans* may play an important role in maintaining plague bacteria among colonial rodents, particularly prairie dogs.

The oriental rat flea, *Xenopsylla cheopis*, lacks both genal and pronotal combs and has the ocular bristle located in front of the eye. This flea is the only species in the United States which has a pigmented spermatheca. *Xenopsylla cheopis* was first described in the Nile Valley and has been introduced via *Rattus* spp. to all parts of the world. This flea occurs throughout most of the United States, being most abundant in the southern states. *Xenopsylla cheopis* also occasionally infests ground squirrels and lagomorphs. Following rat control or when rats vacant their nests, these fleas will also abandon the host or nest for a new host resulting in humans being readily bitten. *Xenopsylla cheopis* is not as commonly found in human habitations as are cat or dog fleas. *Xenopsylla cheopis* is an important vector of urban plague bacteria (flea/domestic rat cycle) and murine typhus rickettsiae, and is an intermediate host for *H. diminuta*.

The sticktight flea, *Echidnophaga gallinacea*, is separated from other flea species presented in this chapter by lacking both genal and pronotal combs. The shape of the head of this species is unique among fleas in that the frontal aspect is distinctly angular when viewed from the side. This small flea primarily occurs on poultry, but is also found on domestic cats and dogs, rats, ground squirrels, lagomorphs, and many other vertebrates, including humans. This flea is most abundant in the southern states. Adult fleas attach themselves firmly to the head and neck of domestic fowl, often causing ulcers. They can become abundant in poultry yards and in adjacent buildings. Besides being nuisances, they also have been found to be naturally infected with plague and experimentally infected with murine typhus, although their habit of remaining attached to a single host most of their lives lessens their importance as vectors.

The northern rat flea, *Nosopsyllus fasciatus*, is characterized by the presence of a pronotal comb, labial palps not extending beyond the trochanter of the first leg, and segment 5 of the hind tarsus with five pairs of lateral planter bristles. This flea occurs on *Rattus* spp. throughout North America and Europe. It is more common in colder areas and is usually the primary flea occurring on *Rattus* spp. in the northern United States and Canada. *Nosopsyllus fasciatus* also occurs on house mice, *Mus musculus*. Although *N. fasciatus* does not readily bite humans, it may be important in transmitting plague from rat-to-rat and was shown to experimentally transmit murine typhus rickettsiae from rat-to-rat. This flea also serves as an intermediate host of *H. diminuta*.

The mouse flea, *Leptopsylla segnis*, has a pronotal comb, a genal comb with four teeth, and lacks eyes. *Leptopsylla segnis* was originally introduced into the United States at a number of port sites on both the east and west coasts but has not dispersed appreciable distances from these original entry sites. This cold weather flea is more commonly found on *Rattus* spp. than on house mice. Although this flea has been experimentally infected with plague bacteria, it is considered to be a poor vector. It has been found naturally infected with murine typhus rickettsiae in China.

The ground squirrel flea, *Oropsylla montana*, has a pronotal comb and labial palps that extend beyond the trochanter of the first leg. This cold weather flea is typically associated with ground squirrels, *Spermophilus* spp., from Nebraska to Texas westward to the Pacific Coast. This flea readily bites humans in the absence of its normal host. Although *O. montana* has been experimentally shown to be a poor vector for plague, populations increase to such huge numbers in nests and burrows that the chances of plague transmission increase significantly. This species is thus considered the primary sylvatic vector for plague in the western United States. In California, its host, the California ground squirrel, *Spermophilus beecheyi*, is considered the most important sylvatic rodent involved with plague and is associated with most human cases of this disease. Based on these findings, *O. montana* and its host, together with another ground squirrel flea, *Hoplopsyllus anomalus*, form a principal complex for amplifying epizootic plague in the western United States.

Other arthropods not belonging to the Order Siphonaptera have been mistakenly named "fleas." For example, small amphipod crustaceans called "sand or beach fleas" (Subclass Malacostraca), found under beached seaweed, are often blamed for bites but they are completely harmless. Instead, people visiting the beach may be bitten by stable flies, *Stomoxys calcitrans*, found in piles of seaweed, or they may be bitten by fleas from a nearby residence. Other crustaceans called "water fleas" (Subclass Branchiopoda) are very common in freshwater pools and also do not bite.

MANAGEMENT AND CONTROL

Flea suppression may be divided into two main categories which include controlling primarily cat and dog fleas in and around premises mostly because they are nuisances, and controlling sylvatic fleas in urban and rural areas for disease prevention and control. Both categories may involve modification of the environment to discourage fleas or their hosts and the use of insecticides for flea control. It is also important to keep in mind that fleas will leave a host when it dies which can result in fleas becoming even worse nuisances or in transmitting disease organisms to other hosts, including humans.

Successfully controlling fleas on cats and dogs involves simultaneously treating these pets and their premises, particularly the pet's favorite indoor sleeping and/or resting places where the various flea stages are most abundant. Where possible, the pet's bedding should be laundered. A vacuum cleaner is recommended to remove accumulations of dust and lint which contain flea eggs, larvae, and pupae. The vacuum cleaner bag should be immediately sealed and disposed of to prevent reinfestation. Preventing reinfestations of pets and premises can be avoided by limiting pets associating with other infested animals.

Once vacuumed, the pet's favorite indoor sleeping and/or resting places, together with associated baseboards and mouldings, can be treated with a residual insecticide. Pesticide application outdoors involves treating entire yards, crawl spaces, and under porches. These subfloor areas should be "rodent-proofed" so as to prevent rodents, as well as stray cats, dogs, or wild animals (opossums, skunks, etc.) from occupying these areas and possibly causing reinfestations.

A veterinarian can recommend insecticidal products to use for flea control on pets. Newer such products include topically applied insecticides with active ingredients containing fipronil or imidacloprid which have been shown to control fleas on dogs and cats for a longer period than insecticidal dusts or dips. Residual insecticides for indoor and outdoors are also effective. Retreatment may be needed within seven to ten days in order to break the egg to adult flea cycle. Follow the label directions for each insecticide to ascertain that the correct insecticide and concentration will be used when treating inside or outside a premises. Insecticides may only be used to control fleas in a manner consistent with the label. Information on how to use currently registered compounds is available from the manufacturer or retailer, a veterinarian (for pet treatment), the Cooperative Extension Service, the local health or agricultural department, or from state and federal agencies.

Preventing flea-associated diseases in urban areas may be accomplished by surveying a specific area to determine the prevalence and abundance of proven flea vectors on domestic rodents, particularly *Rattus* spp. Rodents are livetrapped, anesthetized, fleas collected, and a blood sample taken for pathogens testing. Identification of the species and population densities of fleas and/or blood results, indicating the prevalence of disease, may prompt application of currently registered insecticides for flea control in burrow entrances, runways, wall voids, attics, etc., followed by possible rodent control. Similar procedures are usually undertaken in the event of an actual epizootic of plague, murine typhus, or other disease, except insecticidal control is targeted at the suspected focus of the outbreak. Environmental modification of the premises, such as eliminating food, water, and shelter,

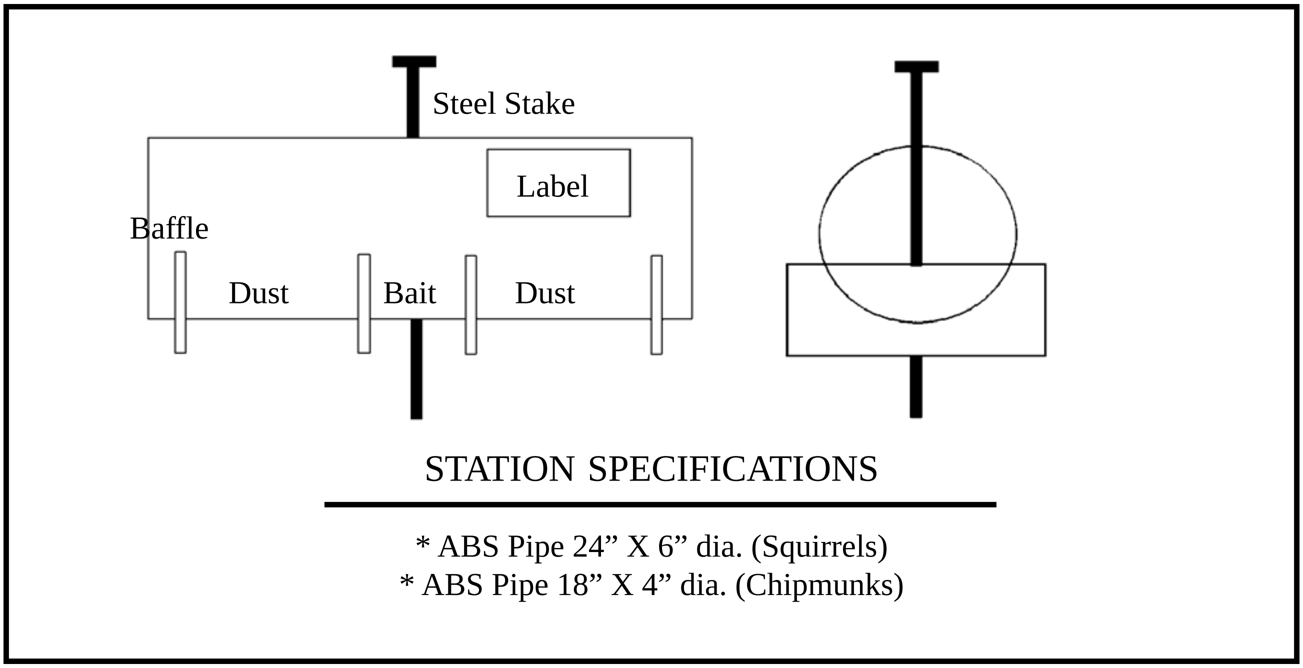

Figure 9-3. Rodent dust bait station (used for flea control).

cutting back excessive foliage, and by "rodent-proofing" buildings ought to be conducted in order to keep rodent populations to a minimum. A continued monitoring and maintenance program should be conducted to prevent the occurrence of future flea-borne disease outbreaks.

As with urban situations, flea control in rural areas also may prevent or reduce flea-associated diseases among sylvan rodent populations (zoonoses). Fleas on these rodents are usually controlled by applying a currently registered insecticidal dust to rodent burrows and/or by maintaining dust-bait stations (Fig. 9-3). For ground squirrels, such a station consists of an 18 inch length of ABS pipe (6 in. dia.) fastened to the ground using a large spike. Smaller stations can be constructed for smaller rodents, such as chipmunks. Unpoisoned bait (to attract the rodents) is placed inside the pipe with insecticide dust placed at each end. When rodents eat the bait they also pick up the dust on their pelage which kills the fleas on them as well as in their burrows and nests. Stations left out longer than a week should be inspected and resupplied, if necessary, with bait and dust. Pre- and posttreatment flea indices are an effective tool used for evaluating the efficacy of flea control efforts. For example, comparing pre- and posttreatment flea counts on sylvan rodents at a given site will indicate if fleas have been reduced to acceptable levels following burrow dusting and/or use of dust-bait stations.

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CHAPTER 10

YELLOW JACKETS, HORNETS, AND WASPS

Franklin Ennik[1] and Minoo B. Madon[2]

INTRODUCTION

Members of the order Hymenoptera are probably the most beneficial of all arthropods. Many species are either parasitic or predatory in their habits, while others are beneficial as pollinators of staple food crops. Most of the approximately 4,000 species of wasps known to occur in the United States of America are solitary and non-pestiferous, stinging other arthropods to obtain their food. Yellow jackets and hornets (family Vespidae, subfamily Vespinae) have the most advanced social colonies. They use their stings as a defense mechanism. Primarily, yellow jackets are a pest species especially in outdoor recreational areas and wherever food may be available (outdoor preparation of food and/or improperly managed garbage). All species in the genera *Paravespula* and *Dolichovespula*, are known as "yellow jackets" in the USA, (commonly referred to as "wasps" in Europe). Yellow jackets are widely distributed in North America except in the desert regions and the higher Alpine forests.

BIONOMICS

Yellow jacket workers are medium sized insects, with a body length of about 1/2 inch (10-15 mm). They have either black/yellow or black/white patterns on the gaster (dorsal surface of the abdomen). These patterns, however, can be confusing to the untrained individual, as the markings of several species are very similar. Due to the complications encountered in the close resemblance of several species, we will not attempt to discuss the specific taxonomic characteristics of each species in this chapter. Therefore, it is recommended that species identification should be confirmed by a taxonomist/entomologist.

Yellow Jackets
(Figure 10-1)

Eleven species of yellow jackets occur in the western United States. Species listed below are those commonly encountered.

Paravespula pensylvanica

This is the most prevalent and widespread pest yellow jacket in the western United States. It occurs in savannah/oak woodland habitats and typically uses abandoned animal burrows, soil cracks, and depressions as nest sites located in fields or on wooded slopes. They respond to both meat baits and chemical butyrate lures. Foragers are present from June to November.

Paravespula vulgaris

This yellow jacket occurs in the wooded areas of northern California and is considered a major pest in the oak/madrone woodland habitat of the northern coast and wooded area of the Sierra mountains. It constructs its nests in ground cavities, in hollow trees, and logs, and in the wall voids and attics of structures. It responds to meat baits but not to chemical butyrate lures. Foragers are present from June to November.

Paravespula atropilosa

Although widely distributed in the western states, this yellow jacket is not frequently encountered because its nests are small, and it usually occurs at higher elevations and more northern latitudes, although occasionally they have been collected from lower elevations. *Paravespula atropilosa* workers are predators only on live prey, such as various arachnids, flies, caterpillars, and aphids. Though not recognized as a pest, foragers will respond to both chemical butyrate lures and meat baits. Foragers are present from June to November.

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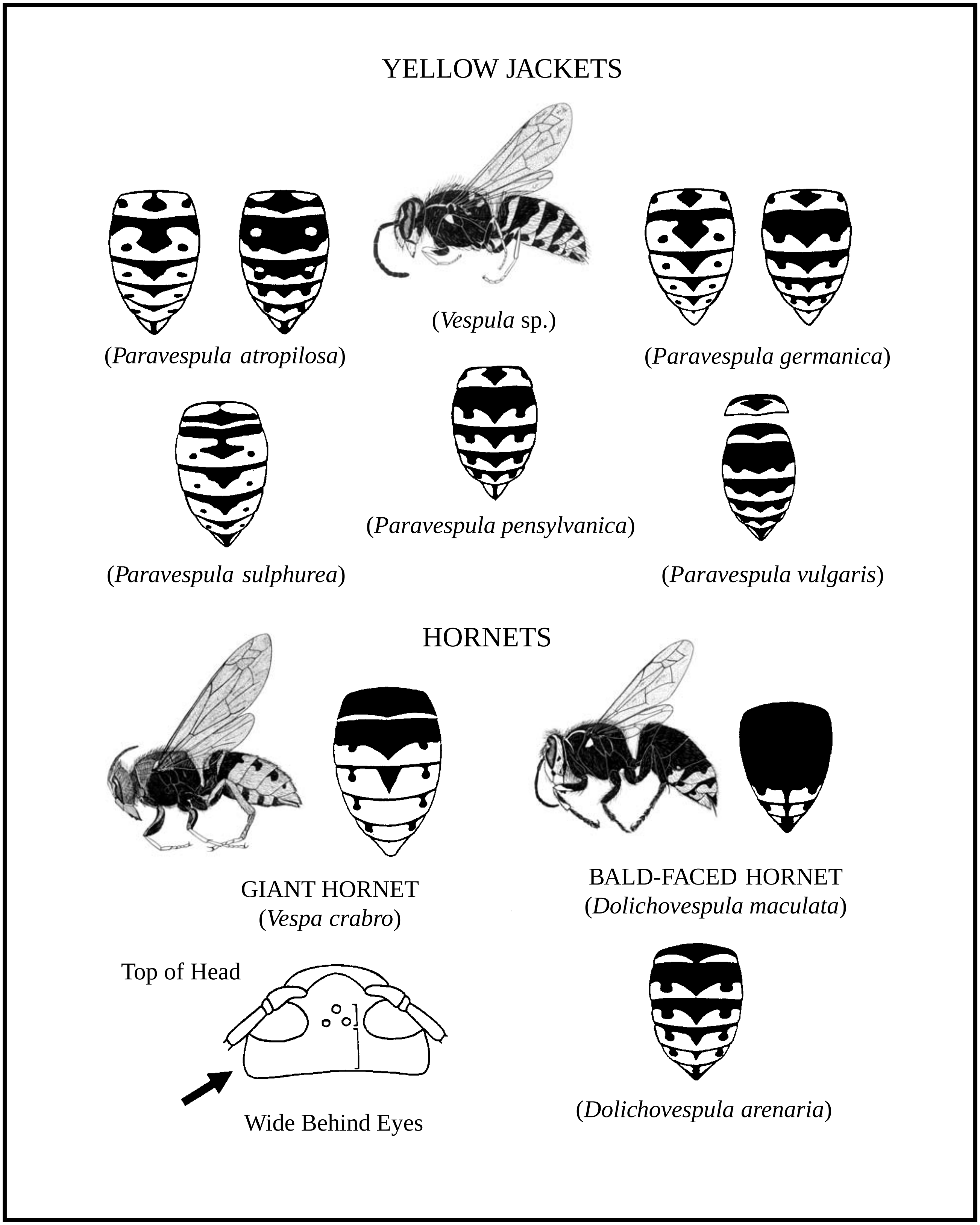

Figure 10-1. Yellow jackets and hornets (courtesy Pictorial Keys, CDC, 1966).

Paravespula germanica

This species is a common pest yellow jacket in Europe that has been imported via commercial transfer to many places around the world. It has been introduced on numerous occasions into the northeastern United States. Beginning in 1975, it began a concerted spread across the temperate, northern half of the United States, via hibernating fertile queens transported in recreational and commercial vehicles. It is now well established in the high mountains of the Sierra Nevada and has been reported along the coast of the western states. Recent surveys have shown that this species is well established and widely distributed in the Greater Los Angeles County area. Large nests are commonly found in Italian Cypress, palm trees, and inside buildings, especially in attics, wall voids, and electrical boxes. This species may be confused with *P. vulgaris* in both habit and appearance. *Paravespula germanica* is expected to establish nests successfully in the cooler areas of the coast and Sierra Ranges in ground sites, hollow trees, and in wall voids and attics of structures. Foragers respond well to meat baits but not to chemical lures. Foragers are present from June to November.

Paravespula sulphurea

This yellow jacket is widespread in California, adjacent Baja California, and southern Arizona; and is often found along riparian creeks where they are observed taking water at the water's edge. This ground-nesting species does not respond to either meat baits or chemical butyrate lures. It is not considered a pest species. Food items consist entirely of spiders and soft bodied insects. Foragers are present from June to November.

Dolichovespula maculata

This large aerial nesting species constructs an oval-shaped paper nest attached to trees and eaves of buildings. It is often referred to as the "white-faced" or "bald-faced hornet" because of its cream and black color and size. It occurs in wooded and forested areas of northern California and is a summertime pest in recreational, rural, and suburban areas. This species responds to meat baits but not to chemical butyrate lures. Foragers are present from May to September.

Dolichovespula arenaria

This large aerial nesting species, which is yellow and black in color, is prevalent in northern California in wooded and suburban areas. It also constructs an oval paper nest attached to trees or buildings. It is not considered a pest except when nests are constructed near walkways and building entrances. This species does not respond to either meat baits or chemical butyrate lures. Food items consist entirely of spiders and soft bodied insects. Foragers are present only from early spring to early summer.

SEASONAL HISTORY

After having mated in the fall, the queen overwinters in sheltered crevices, ground depressions, under the bark of trees, or in buildings. In the spring the founders queen emerges from her hiding place, selects a nest site and constructs a rudimentary paper queen-nest, with an outer covering, consisting of 10 to 15 cells. Eggs are deposited into each cell and these eventually hatch into larvae. The queen feeds masticated insects to the developing larvae; the larvae pupate and eventually emerge as adult workers. While the workers take over all duties of building and maintaining the nest and collecting food, the queen spends all of her time laying eggs. As the colony population increases from a few individuals to many hundreds or thousands, the nest size is enlarged accordingly. During the latter part of the fall season, males and females are produced. As the end of the season approaches, the workers die off; the new queens mate and seek overwintering sites, and the males eventually die. The nest deteriorates and is usually not used again.

Yellow jackets normally feed upon live insects and spiders, plant and insect nectars, and carrion. However, the colonies of some species may increase to a size beyond the food carrying capacity of their habitat. As a result, some species become especially aggressive and troublesome in recreational areas, residential areas, agricultural and food manufacturing operations, and garbage handling facilities. Nests constructed in or near areas of human activity are a source of summertime irritation. Although the list of natural food preferences that yellow jackets may feed on is quite long, the pestiferous species prefer liquids high in carbohydrates and protein sources.

Paper Wasps
(*Polistes* spp.)
(Figure 10-2)

Paper wasps of the genus *Polistes* are widespread in the Nearctic region and are represented by many color forms and subspecies but few species. These wasps are brightly colored, usually black, yellow, white or orange striped, but distinguishable from yellow jackets by their large size and tapered abdomen where it joins the thorax. These social wasps are generally considered economically beneficial but are well-known for their painful stinging ability and may become a nuisance by their presence near human habitation or activities. *Polistes* queens overwinter in sheltered crevices and buildings.

The life history of *Polistes* is similar to that of the yellow jacket. There are at most several hundred *Polistes* in a nest. The nest consists of a single comb without an outer covering. They feed on soft bodied insects, especially caterpillars, and on juices of fruits and honeydew. At times, they may congregate in large numbers on plants where honeydew produced by other insects is present.

Mud Daubers
(*Sceliphron* spp. and *Chalybion* spp.)
(Figure 10-2)

These wasps are widespread in California and are easily recognized by the long, narrow "waist" (the anterior portion of the abdomen is long and slender). They construct nests under eaves of houses and sheds and under porches. The female dauber builds a cluster of clay cells and provisions them with spiders, which have been paralyzed by her sting. She then deposits an egg in the cell and caps it. This process is repeated until a series of 15 to 20 such cells are built side-by-side. The female flies away and does not return, leaving the cells unattended. The eggs eventually hatch, the larvae feed on the paralyzed spiders, and then pupate. The adult emerges in about two weeks, and only males and females are produced (no workers). There may be several generations in a season. Developing larvae are often heavily parasitized by other wasps.

European Hornet
(Vespa crabro)

These large wasps are distinguished by their large body and head size. *Vespa crabro* was accidentally introduced into the eastern coast of the United States and is slowly migrating across the temperate region of North America. It is a brightly colored species whose reddish stripes and large size (25 mm in workers and 35 mm in queens) make it quite noticeable. Nests are constructed of paper, usually in hollow trees or wall voids of houses.

Sting Apparatus
Only the queen and worker caste have a sting. The stinger of social bees and wasps may be barbed (serrated) or relatively smooth with few barbs. In the case of honey bees, the barbed sting and attached venom sac are usually torn out of the body as the bee flies away. The sting and attached sac remain embedded in the skin of the victim and muscles surrounding the venom sac continue to inject the venom. The sting apparatus of yellow jackets, paper wasps, and other wasps, however, is relatively smooth or with few barbs and rarely left in the skin. As a result, the wasp or yellow jacket is able to sting repeatedly. Where possible, stings should be scraped off immediately with a dull blade or straightedged object as this greatly reduces the amount of venom injected.

PUBLIC HEALTH SIGNIFICANCE
(Envenomation)

Most stings, with the exception of infrequent encounters with some solitary forms, such as velvet ants, mud daubers, and some solitary bees, are inflicted by the social forms, such as honey bees, yellow jackets, paper wasps, and hornets. The sting is primarily used against vertebrates as a defensive weapon because the venom injected by the act of the sting contains one or more components that cause intense pain and local tissue damage. Since social wasp colonies are comprised of up to several thousands of individuals, stings are often multiple and therefore more serious. Reported morbidity from bee and wasp stings are usually due to allergy, shock, and renal failure. The number of persons sensitive to the variety of "hymenopterous" venoms in the United States is believed to include at least 2% of the general population.

Reaction to Stings and Treatment
Hymenoptera venoms contain a number of components that cause a variety of responses including allergenic and non-allergenic reactions. Normal reactions to the venom of Hymenoptera following a sting include immediate pain and local swelling. However, reactions vary in intensity, depending upon the sensitivity of the individual. A small percentage of the general population

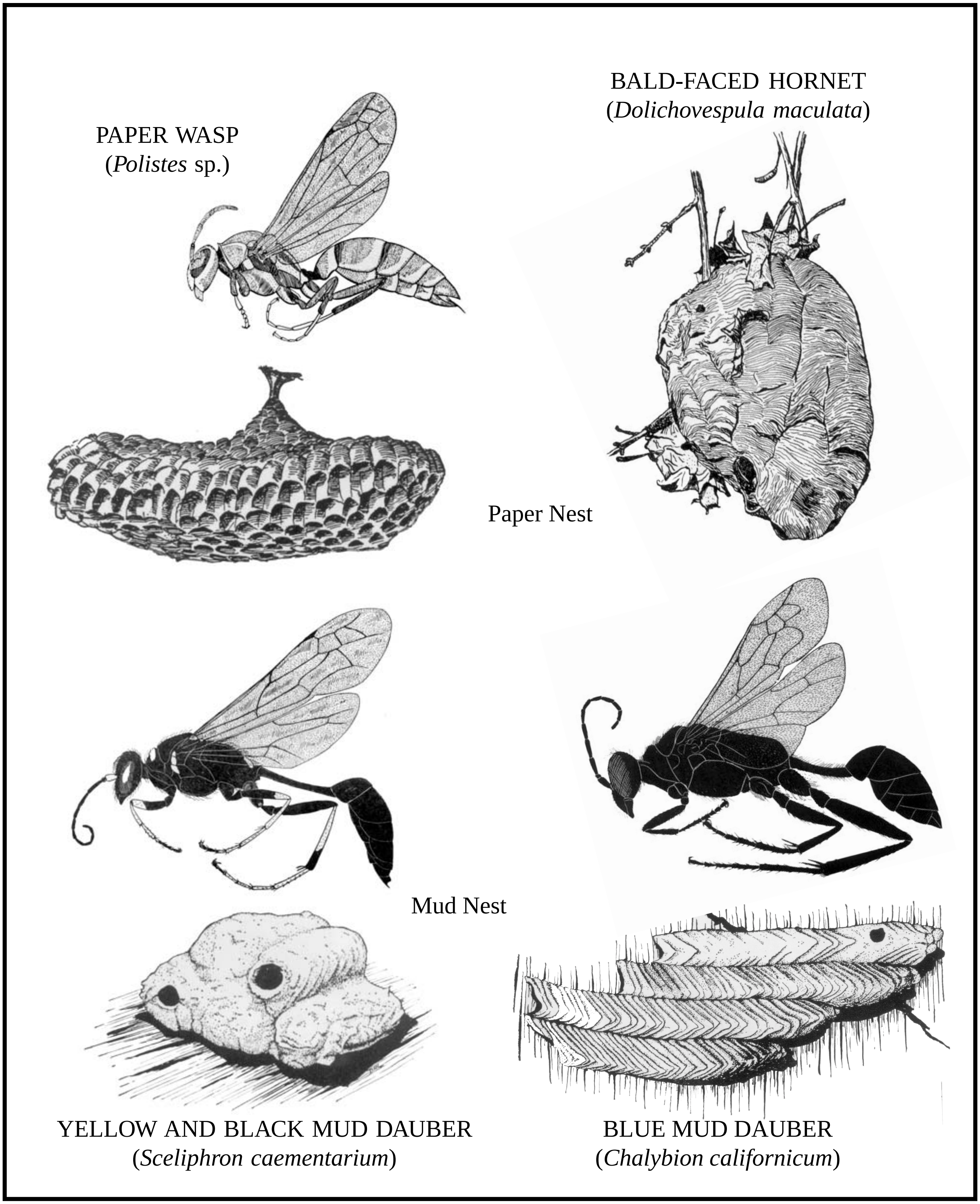

Figure 10-2. Wasps and mud daubers (courtesy Pictorial Keys, CDC, 1966).

is highly allergic to Hymenoptera venom and may develop anaphylactic shock following even one sting. Persons known to be allergic to Hymenoptera stings should wear a Medic Alert bracelet or carry a self-administered epinephrine apparatus.

Persons with few stings and who are not allergic to Hymenoptera stings probably do not need medical treatment; however, they should be observed for unusual sequelae. After removing victims to a safe area, responders should: (1) immediately remove stingers, if any, that are left in the victim's skin; (2) cleanse the sting area with soap and water; (3) apply appropriate topicals and medication to reduce pain and swelling such as ice pack, baking soda, and analgesics.

Treatment of multiple sting victims is entirely supportive since antivenin for the various Hymenoptera is not commercially available.

In moderately sensitive persons, reactions vary and may appear in the form of widespread swellings or hives, wheezing, faintness, dizziness, vomiting, abdominal cramps, or diarrhea. There may also be some shortness of breath, tightness in the throat, and occasionally some aching and swelling of the joints and a bruised appearance of the skin.

Emergency treatment of generalized allergic reactions should be treated promptly with aqueous epinephrine. If shock occurs, appropriate supportive measures, including intravenous fluid therapy, as well as respiratory support may be needed. The goal of therapy in the face of anaphylaxis is to maintain an effective airway, respiratory function, and circulation.

Avoiding Stings

Yellow jackets and wasps are more numerous and active during the spring, late summer, and early fall months. They are less likely to be active in the dark and on cold days. People often attract stinging Hymenoptera into their space with flowering plants, food and cooking odors, open refuse containers, outdoor barbecues, and water sources, such as fish ponds and creeks. Brightly colored clothing and perfumed materials, such as suntan, after-shave lotions, and colognes may also attract yellow jackets.

CONTROL AND MANAGEMENT

Precautions

Use of Protective clothing. Field staff responding to a bee or wasp situation should wear high shoes, which cover the ankles, and a pair of heavy coveralls. The legs of the coveralls should be tied snugly over the shoe tops just above the ankles. Veiled head wear and heavy gloves are also recommended. These articles of clothing may seem rather cumbersome and unnecessary to many operators; but should one unfortunate circumstance arise when they are being worn, their value will become apparent immediately.

Control should preferably be done at night when the insects are in the nest. Persons who are allergic to hymenopteran stings should not undertake control.

Control Methods

The control of pest ground-nesting or aerial yellow jackets, may be considered under three general headings: (1) a nest that is located and accessible; (2) infestation in a small area; and (3) infestation in a large area. The distinction among these three situations cannot always clearly be made, nor can the recommendations be limited exclusively to one situation. It is very important to know the species of yellow jacket/wasp in question. Most yellow jacket/wasp species are not considered pests or may not respond to known control measures.

1. **Accessible ground or aerial nest.** Mark the position of nest opening during the day. At night, introduce an appropriate dust or spray toxicant into the opening of the nest taking all precautions to prevent mass exit of the disturbed yellow jackets or wasps. Avoid the use of lights but if it should be necessary, use a flashlight or other forms of illumination. The light should be positioned away from a person but with the beam directed toward the nest opening in the ground. Be aware that the yellow jackets or wasps that may fly out have a tendency to go toward the light source.

   A pressurized aerosol dispenser that can project a dust or spray stream directly at the nest or downwards at a nest opening on the ground may be used.

2. **Foraging yellow jackets.** When the nests are not located and the nuisance is due to the presence of the foraging yellow jackets, temporary relief may be obtained by trapping and destroying them in traps baited with chemical lures and protein or carbohydrate attractants. Choice of bait depends upon the species of yellow jacket to be

controlled. Many such traps are commercially available.

A water trap consisting of a container of water (to which detergent has been added) with a protein attractant suspended a few inches over the water will remove large numbers of scavenging pest yellow jackets. Yellow jackets attempting to fly away with a piece of protein will fall into the water and drown.

3. A **large area,** such as a public park or picnic ground, may be protected from foraging pest yellow jackets by a poison-baiting program. Several weeks may be required before control is achieved.

The following proposed outline, utilizing a currently registered insecticide in a cat food bait, has proven successful. If necessary, modify the program to fit local conditions. The term "pest yellow jacket" used in this outline refers to those species that are general scavengers that exploit certain human habitations, food processing plants, orchards, recreation sites, animal husbandry operations, garbage dumps, etc. Here, their numbers may increase far beyond those found in natural environments where they are limited by the availability of insect prey and other proteinaceous or carbohydrate foods.

1. Determine the species of pest yellow jacket. Most yellow jacket species are not pests and some do not respond at all to baiting programs. If necessary, obtain the identification services of a knowledgeable entomologist or vector ecologist who can also explain the habits and biology of the species in question.

2. Determine population levels by observing numbers of pest yellow jackets attracted to tuna cat food baits or to the chemical attractant, heptyl/octyl butyrate (optional). Start monitoring population levels in early summer. When numbers of foragers reach sufficient levels (10 - 20 wasps/10 min.), start the baiting program. **Note:** Not all yellow jacket species are meat eaters nor will all respond to chemical lures such as heptyl/octyl butyrate. Monitor traps are optional. These devices provide an indication of the pre- and posttreatment success of the baiting program in large scale operations.

3. Mixtures should contain the currently recommended amount of toxicant. Using more is unnecessary and will increase the repellency of the mixture. For best results, bait dispensers **must** be tended regularly and bait portions replaced at least twice weekly (for example, Monday and Thursday) for the **first two weeks**. Ideally, bait portions should not exceed what can be removed by the yellow jackets in two days. Fresh bait portions should be prepared for each use rather than premixing and freezing portions ahead of time. Use no additives other than water and/or vegetable oil (for moistening agent). Other additives enjoy equivocal or unfavorable results**. Mix thoroughly**.

4. Bait dispensers should be placed in shade or **under** (but not in) trees about 2 meters above ground, around the periphery of the area to be protected.

   Exposing the bait dispenser directly to the sun will cause the bait to dry out and quickly become unattractive to the yellow jackets. It's important to place the bait dispenser early in the day since yellow jackets establish their foraging patterns at sunrise and are reluctant to change them.

   The feeding activity of the pest yellow jackets will be severely reduced after two to four bait exposures (in some cases after the first exposure), depending upon the success of the control effort. A second application of poisoned bait is usually necessary but is not needed until 10 to 14 days later if a drastic reduction of foraging wasps is noticed.

5. Entry holes in bait dispensers should be at least 5/8 to 11/16 inch in diameter. Smaller holes will prevent a yellow jacket with a load of bait from entering or exiting the bait dispenser. Constructed enclosures should be made with 3/4 inch hardware cloth or equivalent.

6. Exposed garbage/trash attracts large numbers of scavenging yellow jackets and wasps. Trash containers with tight fitting lids should be provided in sufficient numbers and in convenient locations. A weekly spray of currently registered insecticide, applied to the inner surfaces of emptied trash containers (especially near the rim) may also be effective. Steam cleaning trash containers once a

month may also be beneficial. Littering undermines the control effort by establishing competing food attractants for pest yellow jackets.

7. Some means of protecting wildlife and children **must** be engineered into constructing and placing the bait dispensers. Bait dispensers must be properly labeled that they contain pesticide.

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CHAPTER 11

COMMON PEST ANTS

Roy R. Snelling[1]

INTRODUCTION

Ants are ubiquitous pests throughout the United States and are common pests especially noted for their persistence. Of the more than 500 species present in the United States, only a small percentage may be ranked as true pests. Occasionally, ants that normally do not enter houses may do so if a building is constructed over their nests or their habitat is otherwise disturbed. Of course, once the members of a colony discover that food may be readily available indoors, they may be difficult to discourage.

Most homeowners consider ants to be unwelcome visitors, attracted to leftover or spilled food. Some species are particularly fond of sweets and others prefer meats or other oily or fatty foods. A few house-invading ants, most notably the fire ants, can deliver painful or troublesome stings. Other ants may encourage and protect plant pests, such as aphids and mealybugs, particularly in yards and gardens. A few species of carpenter ants can cause serious damage to wooden structures, more a problem in the eastern and northern states.

GENERAL CHARACTERISTICS OF ANTS
(Figure 11-1)

Differences Between Ants and Similar Insects

All ant species are social insects, and usually live in populous colonies in soil or in dead wood, whether on the ground or in tree limbs. There are three distinct castes: workers, queens, and males. As a rule, we see only worker ants except under certain circumstances. It is the workers that forage for food and defend the nest from attack. The sole function of the queen is to start a new colony and to then lay the eggs that provide the work force for the colony. Males live only to mate with virgin queens.

Ants are sometimes confused with termites, the latter often mistakenly called “white ants.” They may be easily separated from termites by several distinctive features. Ants have distinctly “elbowed” antennae; the antennae of termites are not elbowed.

Ants have a distinct one or two-segmented waist between the mesosoma and the gaster; termites have no waist-like constriction. Worker ants have compound eyes on the side of the head (very small in thief ants); termite workers are without eyes.

Some wasps are wingless and ant-like in appearance; ants may be distinguished from such wingless wasps by the fact that the segments(s) of the petiole have a distinct dorsal node or “scale.” Such a dorsal node is lacking in those wasps that are without wings. Additionally, all species of wingless wasps are nonsocial.

Winged ants have the front pair of wings much longer than the hind pair; in termites the two pairs are equal in size and appearance. While variable in color, ants are yellowish, reddish, brownish, or blackish, or a combination of two colors; termites (except the winged forms, which are usually black) are dirty-white in color.

In the brief descriptive notes that follow, I use the term **mesosoma** instead of the technically incorrect, but often used, “thorax.” For the same reason, I use **gaster** rather than “abdomen.”

Principle Ant Types

As noted above, ants have a distinct one or two-segmented waist between the mesosoma and the gaster. The first of these two segments is called the petiole and the second (when present) is called the postpetiole. Examples of common pest species with only a single waist segment include members of the subfamilies

[1]Natural History Museum of Los Angeles County, Los Angeles, CA 90007.

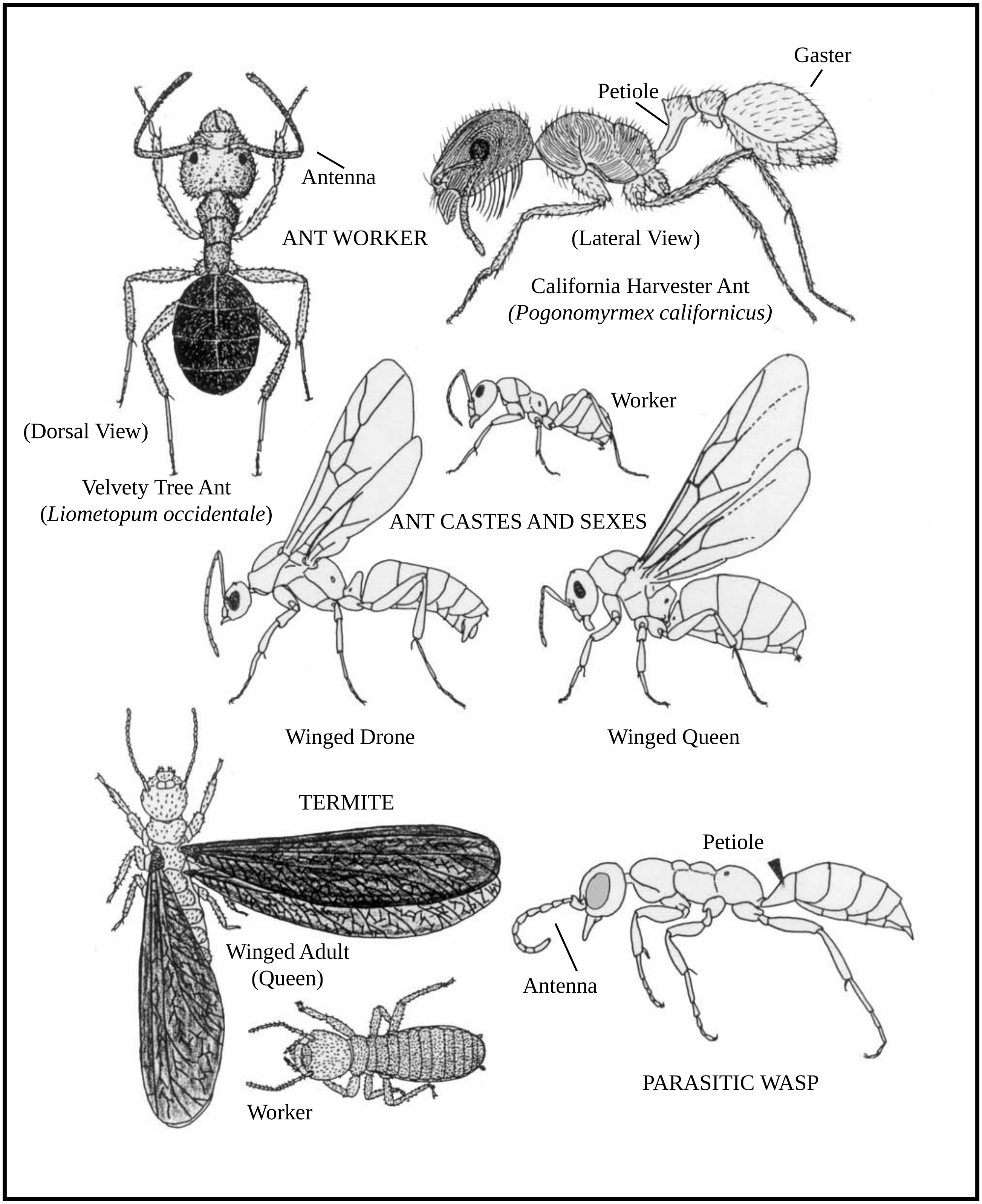

Figure 11-1. Ants and ant-like insects.

Formicinae (carpenter ant and field ant) and Dolichoderinae (Argentine ant, velvety tree ant, and odorous house ant). Pest species with a two-segmented waist all belong the to very large subfamily Myrmicinae (southern fire ant, red harvester ant, black harvester ant, and thief ant).

GENERAL LIFE CYCLE

Ant Castes

All ants are social insects, and the individuals within the ant colony consist of three types: queens, workers, and males.

The **Queen** is the reproductive individual and the mother of other colony members; some ant species have only a single queen within a nest (harvester ant), while other species may have many queens (Argentine ant). Queens may be similar to workers but are larger and more robust: the mesosoma is stout and "blocky" in appearance and the gaster is enlarged. Also, queens of most ant species have a trio of simple eyes at the top of the head, generally not present in workers. Before they mate, queens usually have prominent wings, which are shed after mating.

Workers are just what the name implies; it is they who do all the work of the colony. They gather the food, feed and otherwise tend the larvae and pupae, enlarge the nest, defend it against predators and other disturbances, and see to the well-being of the queen(s). Although female, they are incapable of mating; under certain circumstances they may lay eggs, but since the eggs are sterile they either fail to develop or, if they do, they result only in males. Worker ants are never winged.

Males or drones are the other half of the reproductive process. Like the unmated queens, male ants have wings (which are never shed) and, again like the queens, have a trio of simple eyes at the top of the head. In most ants, the males are distinctly smaller than the queens but larger than workers; they have small heads with very large compound eyes and the mandibles are often small and weak; the mesosoma is robust. Male ants are often black, but may in some species be yellow or reddish. Unlike queens, male ants die after mating.

Development

The life cycle of ants is an example of complete metamorphosis: egg, larva, pupa, adult. Ant eggs are seldom noticed because of their tiny size. They are usually whitish in color and may be found in clusters or packets in nest chambers. The larvae are also usually whitish in color; they start as tiny grubs no larger than the eggs from which they hatch but continue to grow in size; they are legless and usually slightly curled; and they are fed by the workers. When mature, the larva changes into the third stage, the pupa. In ants of the subfamily Formicinae, the pupa spins a cocoon within which it develops to maturity; pupae of Myrmicinae and Dolichoderinae are not enclosed in a cocoon. Whether within or without a cocoon, the fully developed larva molts (sheds its skin) and transforms into an inert, white replica of an adult with all appendages folded closely against the body. As the pupa matures it gradually changes to the colors of the adult and eventually molts and emerges as a new adult member of the colony.

Behavior

Worker ants devote most of their time to the multitude of tasks necessary to the health of the colony; enlarging or repairing damage to the nest tunnels and chambers, tending the brood, attending to the needs of the queen(s), gathering food, and, when necessary, defending the nest from invaders or other disturbances. Several of these worker activities bring the ants into direct and unwelcome contact with man.

Most ants are more or less omnivorous, though often with decided food preferences. Argentine ants, for example, are particularly fond of sweet substances and commonly invade homes in order to get at spilled jams, jellies, honey, sugar, or other sweets. Fire ants and thief ants, on the other hand, are attracted to oils and fats, so show up to devour bits of grease or meat, oily nuts (such as walnuts), butter or margarine, or anything else with high levels of fats.

Ants, such as Argentine ants, odorous house ants, and field ants may also be more than a small nuisance because they also gather the sweet exudates ("honeydew") secreted by aphids and mealybugs feeding on garden and yard plants. The association between the ants and the plant-feeders is often a close one, since the ants commonly protect the aphids and mealybugs from predators and parasites, to the detriment of the plants on which they feed.

A very few species actually live within our homes. Most common of these are the various species of thief ant. These minute ants live in tiny crevices within the structure, such as the joint where structural timbers join, under tile or linoleum, behind wallpaper, within electrical fixtures, or anywhere else that seems a safe place to them. Such nests are often within the kitchen or nearby. From such a safe vantage, the workers venture forth to raid the kitchen for food, most often meats and fats.

Carpenter ants of various species also nest within our homes. Some merely occupy available spaces, such as those between joists, in hollow-core doors, window casements, and other suitable cavities; they seldom do structural damage.

Other species of carpenter ants, however, can and do excavate sound, dry wood and are capable of doing extensive damage to a wooden structure. These species are more common in the eastern and northern states, but also are found in western mountain ranges.

Finally, ants interact with us in another fashion. Some of the Myrmicinae (those with a two-segmented waist) are capable of delivering a painful sting. Most notorious are the several species of fire ants and the red harvester ants. The sting of the red harvester ant is especially painful and the pain may persist for a day or more. Rarely, people are allergic to the venom and may require medical treatment. Fire ant stings, on the other hand, are not especially painful, but often a pustule may develop at the site of the sting. This pustule may ulcerate and the site may then be subject to secondary infection. Often, the site of the pustule may become permanently discolored.

MAJOR PEST SPECIES OF ANTS

There are over 500 species of ants in the United States. The task of accurate identification requires the services of a specialist in ant classification. However, our few usual pest species can generally be recognized without too much difficulty. Access to a dissecting (or binocular) microscope with a magnification of about 45x is best, but not generally available. Reasonably accurate identifications can be made, with practice, using a 10x-15x hand lens.

IMPORTANT PEST SPECIES

Species with a Two-Segmented Waist
(Figure 11-2)

California Harvester Ant (*Pogonomyrmex californicus*) (Fig. 11-1)

This is only one of several species of red harvester ants found in California. Red harvester ants are distinctly red in color (those from our desert areas commonly have the end of the gaster blackish), there is a fringe or “beard” of long hairs on the underside of the head, and the front of the head has numerous very fine, parallel ridges. The California harvester ant is distinguished from other similar species because it does not have a pair of spines on the hind part of the mesosoma.

Red harvester ants are large and live in populous colonies. When disturbed, they are capable of delivering a very painful sting. Workers are active daytime foragers and gather seeds from grasses and other plants, the normal food of these ants. They almost never invade homes, but are frequent pests of yards and other grounds, where they often clear vegetation away from the nest entrance.

Pharaoh Ant (*Monomorium pharaonis*)

Pharaoh ant is an Old World species that has been accidentally introduced into the United States. It has recently been found in southern California and is a common pest species in apartment buildings, where it nests in suitable crevices within the building. It somewhat resembles the southern fire ant, but is more yellowish in color, the tip of the gaster is not black, and the integument is dull, rather than smooth and shiny as in the fire ant.

This is almost exclusively a household ant, rarely a pest outdoors. Indoors, it is attracted to a wide variety of food stuffs, particularly meats, but will also go after sweets. The ant cannot sting and is otherwise harmless.

Thief Ant (*Solenopsis molesta* group)

Although most often identified as a single species, *Solenopsis molesta*, there are actually several species of thief ants in the United States. All of them are minute, inconspicuous yellowish ants; the true *S. molesta* appears to be an eastern species. They are called thief ants because they often live within, or very near, the nests of larger ant species and prey upon the larvae and pupae of the larger ants.

The various species of thief ant are important as house-infesting species, but often go unnoticed because of their small size and secretive habits. Thief ants are especially fond of fatty foods, such as bacon, ham, other prepared meats, butter, or margarine. They also commonly infest stored nuts with high oil content (such as walnuts). Although they will eat cheese, other foods such as sweets, fruits, or starches are generally not attractive to them. Unobservant people, or those with failing

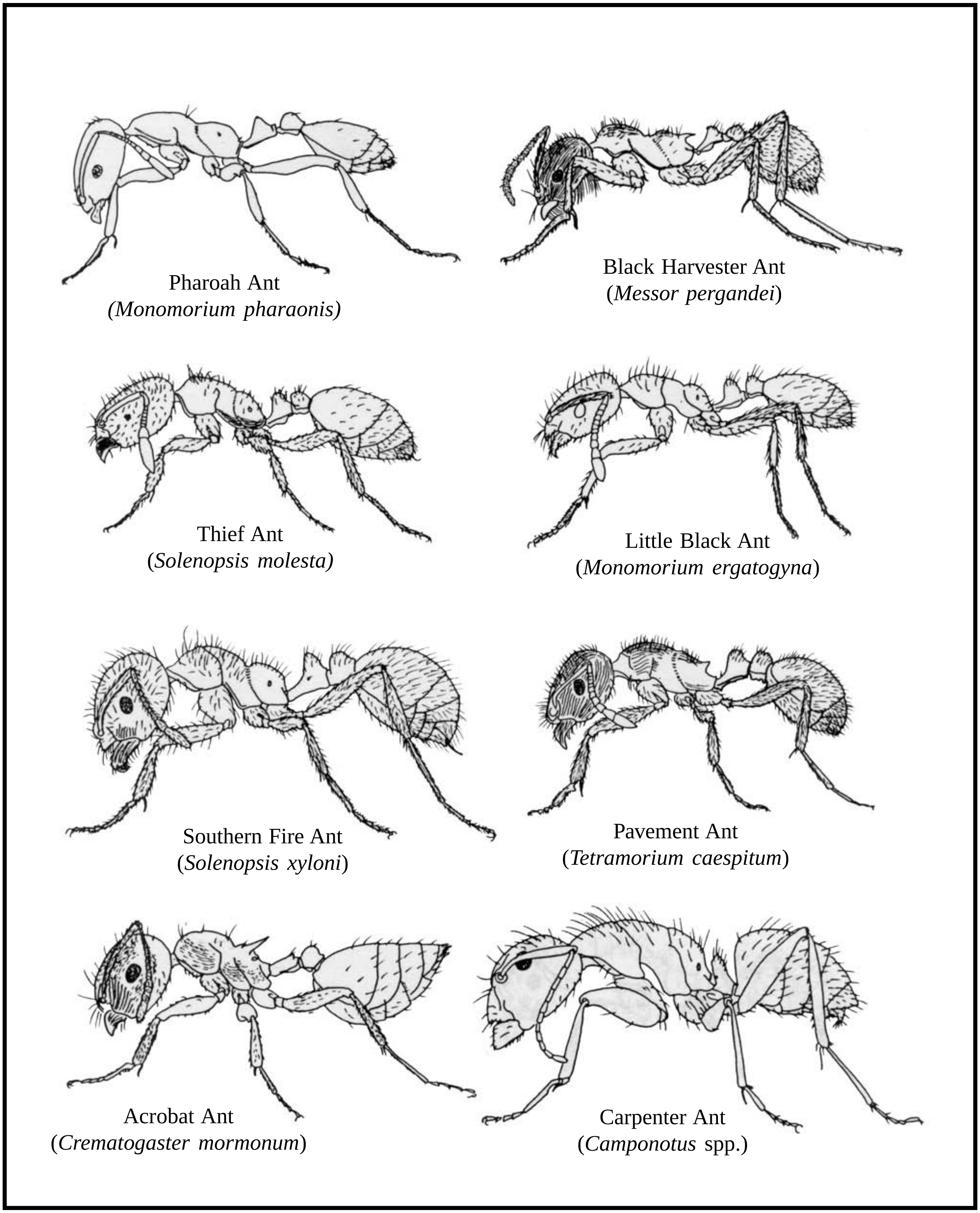

Figure 11-2. Worker ants.

eyesight, may complain about peculiar tasting food without realizing that it is actually covered with ants!

Southern Fire Ant (*Solenopsis xyloni*)

Among those pest species with a two-segmented waist, the southern fire ant is our most serious pest. It is a common species in central and southern California. Nests are in soil and a nest may have several entrances, often in series, and characterized by "messy," irregular mounds of fine soil. Nests may also be beneath objects on the ground, such as stones, boards, cow chips, concrete slabs (such as sidewalks and driveways), or other cover. This species ranges across the entire southern United States.

The southern fire ant is a species with several sizes of workers, from the small "minors" to the considerably larger "majors." Minors predominate in any colony. These ants are usually shiny red, with the end of the gaster blackish. The shininess, together with the variations in size, make southern fire ants fairly easy to recognize.

When a colony is disturbed, the workers rush out by the hundreds, ready to defend the nest with their fiery sting. They swarm over an invader, biting and stinging. Stings almost always result in a painful itching that may persist for several days. A small pustule may develop at the sting site and may eventually form a small ulceration subject to secondary infection. When healed, the sting site may remain marked by a tiny brown spot.

The southern fire ant is an omnivore, attracted to sweets of all kinds, but is especially fond of fatty foods. They are also active predators on other insects, including other ants; and in disturbed habitats will sometimes eliminate all other ants, except Argentine ants. These two species generally do not occur together. This species is also known to attack young of small mammals and bird hatchlings. The southern fire ant is a common pest in poultry farms, often infesting the grain fed to the birds (particularly if yellow corn is present) and attacking the birds, especially chicks.

Red Imported Fire Ant (*Solenopsis invicta*) (Figure 11-3)

The red imported fire ant or RIFA is one of a growing number of "invasive species" that have been introduced

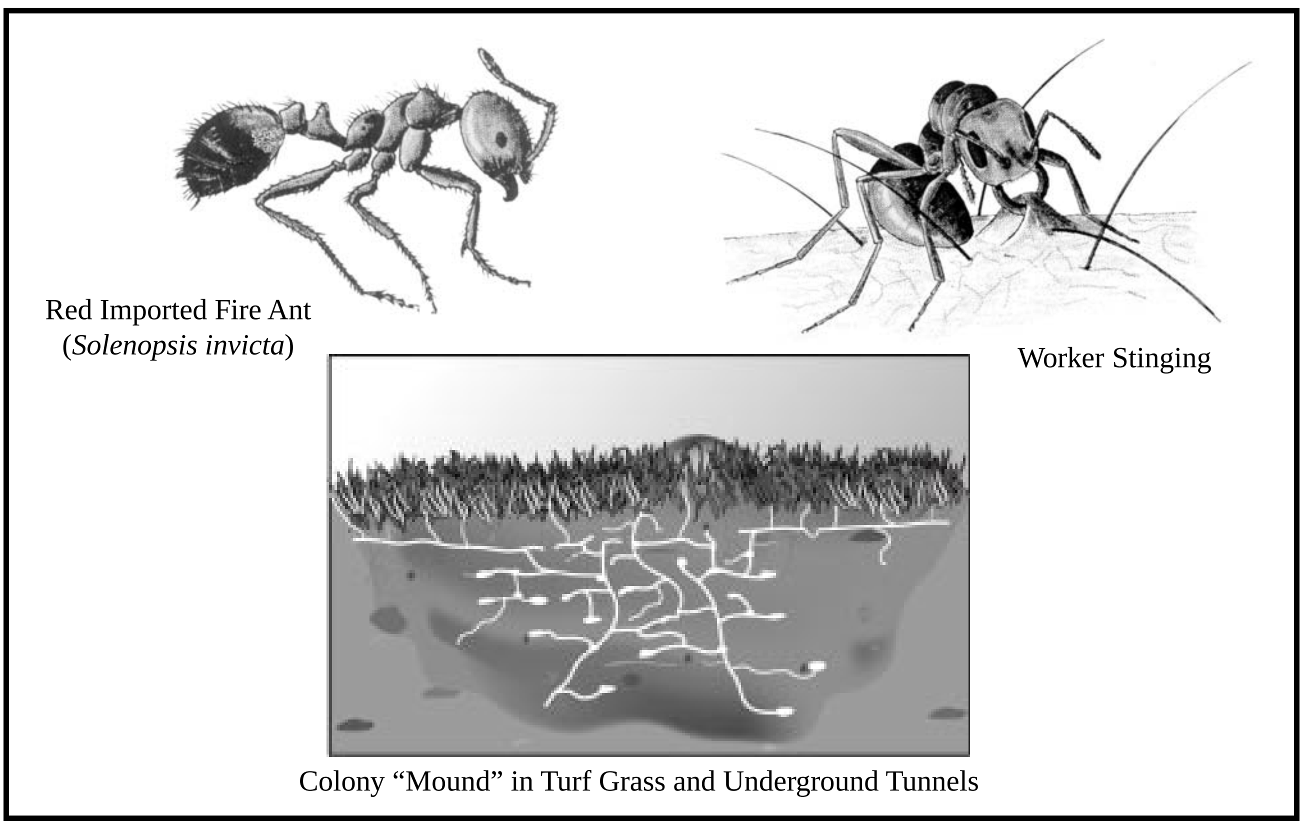

Figure 11-3. Red imported fire ant (courtesy Papp and Swan, 1983).

into California with the potential of costing millions in health and agricultural damage. The species, which is native to South America and capable of delivering a painful sting, was first introduced into the southeastern United States (Alabama) in the early 1930s. It has since spread quickly throughout the area and currently infestations have been discovered in southern and central California, particularly Orange and Riverside Counties.

Wherever RIFA is encountered in abundance (look for the characteristic "mound"), the species has literally changed the local way of life. The predatory habits of RIFA, combined with its sheer numbers, consumes much of the ground dwelling wildlife within its range. Eventually, many soil inhabiting organisms, including reptiles and birds (e.g., quail), are eliminated. From a human standpoint, their stinging habits and typical high attack rates have produced a situation where humans can no longer enjoy routine outdoor activities without fear of being attacked. Normal activities, including yard maintenance, gardening, playground activities, hiking, and sporting events, have all been changed from an enjoyment activity to a distinctly defensive activity. In some instances outdoor picnics have been moved from the lawn to the street!

Description (Figure 11-3): The red imported fire ant is recognized from most other ants by the colony "mound" and the variable size of the worker caste, which contains both large (majors) and small (minors) individuals. It is further distinguished from closely related fire ants by the presence of a marginal "tooth" on the clypeus. On the average, major workers are 1/4 in. (6-7 mm) while minor workers are 1/8 in. (3-4 mm) in length. Queens and drones, both referred to as alates (winged), are considerably larger from 3/8 in. to almost 1/2 in. (8-12 mm).

The typical RIFA colony or mound is recognized by its characteristic dome shape and granular surface appearance. Active mounds normally range in size from 8 to 36 in. (20 to 100 cm) in diameter to over 18 in. (50 cm) in height. Most, however, are the size of a typical "gopher mound." Active colonies started by a founder queen do not appear above ground for six months, at which time the mound is too small to be recognized. However, in about nine months the mound begins to grow quickly, and after one year the average size is reached. Within the mound, both above and below ground level, the interior or central chamber is comprised of a "sponge" network of small interconnecting galleries or cells. The cellular network is further connected to the water table by a series of tunnels extending beneath the central chamber. A mature RIFA colony may contain as many as 250,000 to 500,000 workers and hundreds of alates.

Detection: One rule-of-thumb that vector control technicians learn about RIFA is the fact that just because there are no mounds does not mean that no RIFA are present. Generally, most RIFA go undetected until the "mature" mound suddenly appears. In the absence of mounds, RIFA are strongly attracted to high protein baits and vegetable oils. Monitoring programs use baits consisting of canned meat, pet foods, and potato chips fried in high calorie vegetable oils, and placed inside a plastic mesh "cage." Baits are usually arrayed in a grid pattern at intervals of 25 to 50 ft. to detect the presence of foraging workers. Spacing is set to include the average foraging distance of workers determined to approximate 50 ft. under normal circumstances. Bait placements often are flagged (red or yellow) to help survey technicians retrieve each placement plus assist with the visual aspect of a proper grid alignment/array.

Control and Management: Sustained control of RIFA is an ongoing and rapidly developing management science. To date, no one methodology appears to achieve long lasting suppression of colonies. The more successful Integrated Pest Management (IPM) programs use a combination of bait formulations of insect growth regulators combined with metabolic inhibitors in a "two-step" (e.g., "Texas two-step") method that produces the longest sustained period of suppression. Colonies also can be treated by drenching the mound with conventional labeled materials that in the long-term produce only short-term control. Baits, by comparison, are carried by foraging workers inside the colony where the oils containing the Insect Growth Regulator/ Metabolic Inhibitor (IGR/MI) are distributed among the colony inhabitants. IGRs destroy a colony by sterilizing the single queen (monogyne colony) or multiple queens (polygyne colony); and in the absence of new worker production, the colony eventually dies out in two to six months. MI baits work more quickly than IGRs by quickly killing the queen or queens, plus all the workers and alates. Best public health protection is via the two-step method with the one-two sterilization and worker kill (quickly eliminates stinging risk if only an IGR is used).

Species with a One-Segmented Waist
(Figure 11-4)

Subfamily Dolichoderinae

This is one of the two major groupings of ants with a one-segmented petiole. These ants are usually characterized by having a distinctive rank, rancid odor when crushed (less pronounced in the Argentine ant, but noticeable when several are crushed together). They are similar to the other group with one-segmented petiole, the Formicinae, but have the end of the gaster blunt and do not have an acidopore (see Formicinae). In both of these groups, there is no sting. Dolichoderinae, in general, have the eyes placed more on the front of the head, while in the Formicinae they are definitely at the side of the head.

Argentine Ant (*Linepithema humile*)

This ant has been known in previous literature as *Iridomyrmex humilis,* but taxonomists have recently determined that true *Iridomyrmex* are limited to the Australasian Region. There are no species of true *Iridomyrmex* in the New World.

In appearance, they are uniformly light to dark brown, often appearing black and they are nearly devoid of hairs except a few on the tip of the gaster. Superficially similar to the odorous house ant, they are separated by the very weak odor when crushed and by the fact that the scale of the petiole is visible when the ant is viewed from above (in odorous house ants the scale is very small and closely appressed to the petiole peduncle and is not visible from above).

This is unquestionably our most important pest ant species. It thrives in our urban and suburban environments where native ant species will not. In some areas it may be almost the only ant species present, especially nesting outdoors. This species does not, however, fare so well in rural or less disturbed habitats. But, in urban situations, the Argentine ant out-competes and overwhelms all other ant species, repeatedly attacking their nests until the other species are eliminated. Colonies number into the hundreds of thousands, perhaps exceeding one million; there are multiple queens.

The Argentine ant is the most frequently encountered ant both indoors and out. Inside, it is an omnivore, attracted to almost any food item, but especially so to sweets. Outside, it is a predator on almost any insect or other arthropod, and also a pest that tends aphids and mealybugs from which it solicits honeydew. Nests may be virtually anywhere, but usually are under a covering object of some sort in direct contact with the ground. But they also nest in potted plants, both outdoors and indoors, and in piles of leaves, mulch, or compost, under bark of firewood logs, as well as a variety of other situations.

Argentine ants nest outdoors across the southern United States. In more northern climes, with their cold winters, it is sometimes present, living mostly within structures, especially greenhouses. Because of the enormous size of colonies, their omnivorous habits, and great adaptability, this is an especially difficult species to control.

Odorous House Ant (*Tapinoma sessile*)

Although somewhat similar in appearance to the Argentine ant, the odorous house ant tends to be darker, almost black, in color; and a single individual, when crushed, produces an especially disagreeable, foul odor. It is also distinguished from the Argentine ant by the fact that when viewed in profile, the base of the gaster distinctly overhangs the petiole, which is completely hidden when viewed from above (NOTE: a 10x hand lens is necessary to clearly see this feature).

This ant is found throughout the United States, but in most areas of the southern part of its range it has been largely supplanted in urban areas by the Argentine ant. In many ways it is similar to the Argentine ant. The colonies are populous (but generally much smaller than those of the Argentine ant) and have a number of queens. The workers forage in trails and they are omnivores that prey on other insects, tend aphids and mealybugs for honeydew, and invade houses for sweets and other food items.

Although generally a ground-nesting ant, the odorous house ant may invade structures, often nesting in wall voids particularly around hot water pipes and heaters. This species may also nest in dead or rotting limbs on trees, from which it often has access to houses or apartments. Like the Argentine ant, it may also nest in potted plants, especially indoor plants during the winter months.

Velvety Tree Ant (*Liometopum occidentale*)
(Figure 11-1)

This ant is found from oak woodlands in central California to moderate elevations in the mountains. It is present also in southern California and even extends into

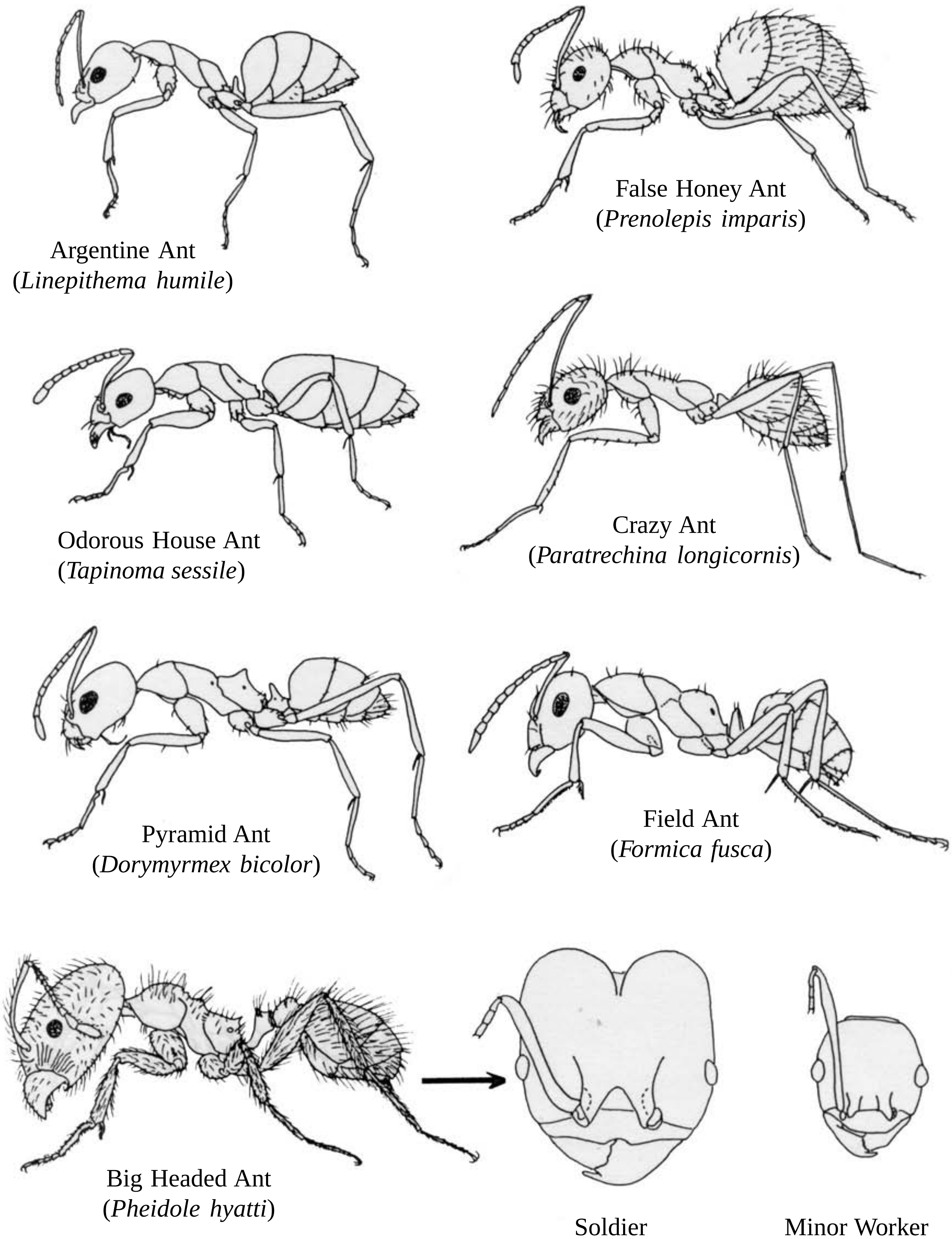

Figure 11-4. Worker ants.

the Mojave Desert along cottonwood lined streams. Workers vary greatly in size, from small (ca. 1/8 in.) to medium-sized (1/4 in.). In larger workers, the head is distinctly heart-shaped (Fig. 11-1); the head and mesosoma are usually dull reddish and the gaster is blackish; and the gaster is densely covered with fine appressed hairs (which are distinctly divergent from the midline) and appears distinctly "velvety," hence the common name. When crushed, the ants have an especially repugnant odor.

Colonies are large and may be located in dead logs, in stumps, in soil, among piles of rocks, or in dead tree limbs. In the central valleys and foothills it is most often associated with oaks, but in southern California it is commonly found with cottonwood trees.

Velvety tree ants often forage considerable distances in conspicuous columns. They tend honeydew producing insects and are predators on other arthropods. They can become pests in picnic or barbecue areas, getting into food.

Subfamily Formicinae

Formicine ants comprise the other major group with a one-segmented petiole. They may be distinguished from the species of Dolichoderinae by the fact that when crushed they produce a sharp, vinegar-like smell; and the tip of the gaster is pointed, with a distinct nozzle-like structure (the acidopore) that has a fringe of hairs along the rim (NOTE: a 10x hand lens is necessary to see this structure). Like the Dolichoderinae they do not sting but will bite and then spray formic acid from the acidopore into the torn skin. When inhaled in any quantity, the formic acid causes temporary respiratory distress.

Our only serious pest species in the Formicinae are carpenter ants, of which over a dozen species occur in California.

Carpenter Ants (*Camponotus* spp.) (Figure 11-2)

There are basically two types of so-called "carpenter ants"; those that nest in wood and those that nest in soil. The latter, obviously, should not be called carpenter ants since they do not attack wood. Of those species of *Camponotus* that do nest in wood, there are again two types; those that actively excavate galleries in sound, dry wood and those that nest almost exclusively in preexisting cavities (such as old termite or beetle galleries or in wood softened by dry rot).

True, wood-damaging carpenter ants are our largest ants. The large workers (majors) are up to about one-third inch long; the smallest workers (minors) may be only about one-quarter inch or less in length. Our species are dark brown to blackish; and the only species commonly associated with wood damage in California is *Camponotus modoc*, a dull, blackish ant with red legs and golden yellow hairs on the gaster. It is found in the Sierra Nevada, from moderate to high elevations.

Another true carpenter ant in California is *Camponotus laevigatus*, another montane species, entirely shiny black with white hairs. It is seldom associated with structures however. Both of these species are usually found in dead conifer logs. They excavate extensive galleries in the wood and may severely weaken the wood if it is a structural timber. *Camponotus modoc* is often found nesting in log houses.

Of those species that generally nest in preexisting cavities, only *Camponotus clarithorax* is at all common. It is especially common in southern California, where it nests in wall voids, window casements, hollow core doors, between joists, under shingles, and in wood already excavated by termites or wood-boring beetles. It is sometimes also found in wood damaged by dry rot. There is little evidence to suggest that these species actively excavate sound wood. Other common species include *Camponotus essigi* and *Camponotus hyatti*.

All carpenter ants are omnivorous, but with a predilection for sweet carbohydrates, so may be found attracted to all manner of sweets. They are sometimes a nuisance at picnics, but are generally too timid to present a real problem. The workers can bite, and the largest workers can even draw blood; they do not sting.

MINOR PEST SPECIES OF ANTS
Species with Two-Segmented Petiole
(Figure 11-2)

Acrobat Ant (*Crematogaster mormonum* group)

These ants, of which there are several species in our area, are recognizable by the peculiar heart-shaped gaster (when viewed from above), which is turned forward over the mesosoma when the ants are disturbed. These ants most often are found nesting in slightly damp, well-decayed tree limbs. When disturbed, they may bite but cannot sting. Although they rarely invade houses, they can be a minor yard pest because they tend honeydew producing insects.

Black Harvester Ant (*Messor pergandei*)

These ants were formerly placed in the synonymous genus *Veromessor*. This is a desert ant that ranges north along the western margins of the San Joaquin Valley. It is distinctive because it is shiny black and has a characteristic "beard" on the underside of the head. The nest entrance is a small crater and is usually surrounded by a distinct chaff ring. The workers, which come in a variety of sizes, forage in the morning and in late afternoon, forming conspicuous files that may extend several hundred feet from the nest. These ants feed almost exclusively on seeds and are seldom anything more than a minor nuisance. Although they can bite, they cannot sting. Other species, usually reddish in color and without so pronounced a "beard" occur in the foothills of the central valleys. They are similar in appearance to the red harvester ants, but cannot sting, do not forage during the hot part of the day, and their nests are surrounded by conspicuous chaff rings.

Little Black Ant (*Monomorium ergatogyna*)

This minute, shiny, jet black ant was formerly included with the eastern species, *Monomorium minimum*, but has been shown to be a separate species. It is common along the coast and throughout southern and central California. It seldom invades houses, but may occasionally show up where it is attracted to both sweets and meats.

Pavement Ant (*Tetramorium caespitum*)

This is an introduced European ant and is a moderately important pest species in the eastern states. In California it seems to be found only in the central valleys and is especially common in the Sacramento area. Two other species of *Tetramorium,* also introduced from the Old World, are found in southern California. None of these seems to have become a problem in California.

Nests are often situated beneath sidewalks, hence the common name for these ants. Among our urban ants, species of *Tetramorium* may be recognized by the presence of fine, regular parallel ridges on the front of the head and the top of the mesosoma, the dull reddish or brownish color, and the pair of short spines on the propodeum.

Big Headed Ant (*Pheidole hyatti*)

There are many species of *Pheidole* native to California (and a few introduced species), most of which are small, inconspicuous ants that do not survive in disturbed urban habitats. Of these native species, only *P. hyatti* occasionally invades homes. *Pheidole hyatti* is common along the southern California coast and the coastal valleys, north to about Monterey County. It is also common in the San Joaquin Valley and the Mojave Desert.

Nests of this species are populous and several queens is the rule. In addition to the slender, long- legged workers, the colony includes the so-called "soldiers," individuals with exaggeratedly large heads. Most species of *Pheidole* are seed-harvesting ants; these so-called "soldiers" actually have as their primary function the crushing of hard seeds. Although often rather clumsy, they can be effective in colony defense as well.

The workers are active and aggressive foragers capable of out-competing most ants other than the Argentine ant. Unlike most other species of *Pheidole*, *P. hyatti* is not primarily a seed-harvester, but is an active predator on other insects. While the ants lack a sting, they overwhelm their prey then "spread-eagle" it, following which it is dismembered and carried back to the nest.

Soldiers are separable from all our other species of *Pheidole*, and from all the other ants listed here, by the fact that the antennal scape is distinctly flattened and broadened and curved at the base. In both worker subcastes the body color is generally a sordid yellowish to brownish; minor workers have very long legs and antennae. Both majors ("soldiers") and minors ("workers") impart a disagreeable fetid odor when crushed.

Species with One-Segmented Petiole
(Figure 11-4)

Pyramid Ants (*Dorymyrmex bicolor* and *Dorymyrmex insanus*)

These species belong to the Dolichoderinae and have the characteristic rancid smell of dolichoderines when crushed. They may be recognized among our ants with one-segmented petiole by the presence of a distinctly pyramid-shaped elevation on the posterior part of the mesosoma when seen in profile. *Dorymyrmex bicolor* has a red head and mesosoma and a black gaster; *Dorymyrmex insanus* (formerly called *D. pyramicus*) is entirely brown or blackish.

Both species nest in open, grassy areas, where their nests are marked by especially tidy crater-shaped cones. The ants are aggressively omnivorous, readily attacking other insects, and also strongly attracted to sweets. They seldom invade houses and are rarely a pest.

False Honey Ant (*Prenolepis imparis*)

The term "honey ant" is correctly applied only to the ants of the genus *Myrmecocystus*, a desert group that includes no species of pestiferous importance. So, I am here introducing the term "false honey ant" for this unrelated species.

This is another member of the Formicinae, usually shiny blackish in color and with a conspicuously large and pointed gaster. It often invades houses in search of sweets and during dry weather may show up in search of water. It is an especially common house ant in the San Francisco Bay region.

Crazy Ant (*Paratrechina longicornis*)

This is another introduced species, presumably originally an Indian species, but now widely distributed by commerce throughout most tropical and many temperate climes. So far, in California it seems to be limited to urban areas of a few southern counties. Among our ant species the crazy ant is identified by its exceptionally long antennae and legs. The body is dark brown or blackish, with a distinctive bluish reflection and is covered with unusually coarse, long seta-like ("spiky") hairs. When disturbed, the ants rush about in a highly agitated and erratic manner, hence the common name.

As a pest in California, the crazy ant seems distinctly minor, largely due, perhaps, to the ubiquitous Argentine ant. Another species partial to sweets, the crazy ant will invade homes now and then, and may be found as a scavenger in garbage. In short, this species occupies much the same niche as the Argentine ant.

Field Ant (*Formica fusca* group)

Field ants belong to the Formicinae and when crushed they impart the distinctive sharply acrid vinegar-like aroma of formic acid (which was first isolated from ants of this genus, whence the name formic acid). There are many species of field ant in California and they vary greatly in color; from rather somber, dull reddish with blackish gasters to dull brown or dull blackish. They seldom are pests except in yards and gardens where they may construct their nests, creating unsightly mounds in otherwise nice lawns. They do solicit and protect honeydew producing insects. Occasionally they may become picnic pests.

Wood Ant (*Formica rufa* group) (not illustrated)

About a dozen species of wood ants occur in California at moderate to high elevations in the mountains. All the species are conspicuously red with black gasters. Nests are very populous and are usually situated adjacent to logs or stones and are marked by conspicuous mounds of thatch (pine needles, juniper leaves, bits of twigs, etc.). The workers are aggressive daytime predators of other insects but are also fond of honeydew and other sweets. When the nest is disturbed, they pour out by the hundreds to defend the nest. Many will stand on the thatch mound and spray formic acid, while others attack the invader with their mandibles and spray acid into the wound. As a rule, they are only picnic pests, but picnic pests of the most aggressive, persistent, and disagreeable sort.

Both field ants and wood ants can be distinguished from carpenter ants by the biconvex mesosomal profile (i.e., the propodeum is lower than the anterior part of the mesosoma, while in carpenter ants, the profile of the mesosoma forms a single even convexity).

ANT CONTROL

Preparation for Control

The correct control method to be used depends largely on the ant species involved and upon the nature and location of the infestation to be treated. The ability to identify the ants will aid the operator in deciding where to begin searching for the source of the problem.

Pesticides must not be used in a manner inconsistent with label instructions. Information on current registered uses of specific compounds is available from the manufacturer or retailer. Sources of up-to-date pesticide use recommendations include industry representatives, the Cooperative Extension Service, County Agricultural Commissioners Office, local health and environmental departments; and technical experts in universities and colleges and state and federal agencies.

Control Procedures

Inside a Structure: Ants that frequently nest indoors are the southern fire ant, odorous house ant, carpenter ant, and thief ant. Try to locate the nest by following trails of ants back to their source.

Argentine Ant

Control of the Argentine ant cannot be achieved inside a structure. However, when working within structures, it is sometimes necessary to show a quick kill of visible ants for the sake of customer satisfaction and good public relations. Any of the commonly used inside sprays will do for this cosmetic purpose.

On new concrete slab construction, dusts or liquids should be applied to all cold joints, wall voids and plates, trims, moldings, cracks and crevices, and any other points of entry. Repeated applications are the rule rather than the exception.

Southern Fire Ant

Treat around moldings, in closets, around conduits, plumbing inspection plates, light fixtures, and switch plates. It is occasionally necessary to treat attics in unusual circumstances.

Thief Ant

Tracing thief ants to their nests is often difficult, therefore, specific procedures are required. Conduits, shelves, the under areas of sinks, cracks, and crevices must all be treated. If it is not possible to apply dusts through gaps under baseboards or thresholds, these must be drilled to provide entry holes through which dusts may be forced. A film of spray should then be applied to the outer surfaces of baseboards or thresholds. In the kitchen, spray inside cabinets and under sinks, baseboards, and thresholds after all dishes, eating utensils, and food have been removed.

Odorous House Ant

This ant is difficult to control because the nests or points of entry frequently cannot be located. Treat behind switch plates, around conduits, TV antenna lead-ins, gas pipes, or any other break in the wall. In the kitchen, remove dishes, eating utensils, and foods and spray inside cabinets, under sinks, baseboards, and thresholds. Treat wall and cabinet voids by drilling a small hole into the void, then inject dust with a bulb or bellows hand duster.

Carpenter Ant

Carpenter ants are not always easy to control. The nest must first be located. Look for very fine wood shavings around the inside of the structure. Use a stethoscope and tap on hollow core doors, listen for the scurrying sound of the ants, and then use a flushing agent. Find out from the occupant whether the ants have been seen in a particular place, then examine that area closely. Once the nest has been located, drill small holes in the window sills, into wall voids, or above places where the indications of a nest are visible and treat these locally, trying to get a general dispersal of material through the galleries. Spray window sills and roof shingles. Baits may also be used to good effect.

Yard and Garden: If ants are nesting outdoors, try to locate the colony by following workers back to their nests. Often the colonies are evident, but those in walls, under pavement, in stonework, or other places may be difficult to locate. If nests can be found, they can be treated directly. If not, other measures are required, such as power spraying the entire infested area.

Argentine Ant

Treat the entire subarea with dusts, taking care to apply the material through a vent that will accept it (not against air currents) or apply liquid emulsions, giving special attention to raised foundations. Make certain that pets are excluded from treated areas by replacing torn or missing screen.

It is important to trace the infestation to its original source and destroy the nest if possible. If not, perimeter treatment of the structure is required; a barrier of residual insecticide around the house to keep ants out. Spray the entire outside perimeter up to the bottom of first floor windows and include a border strip of treated soil about one meter (3.3 ft.) wide. All pillars, pipe porches, supports, and vegetation by which ants might enter the structure must be treated.

Southern Fire Ant

Locate and treat nests with sprays or granules. Important areas to treat are around trees, stones, curbs, parkways, stepping stones (under, if possible), and places where grass and pavement meet. Treat the entire subarea and yard if necessary.

Velvety Tree Ant

When treating for this ant, pay particular attention to spraying crotches of trees. When trees are located near windows or other means of ingress, the ants may invade the house.

Red Harvester Ant

Locate and treat the nest. Direct treatment is best accomplished by spraying the nest entrance and surrounding area, thoroughly drenching the soil, then covering with a weighted tarp for 24 hours.

Odorous House Ant

Power spray the entire yard and structure subarea for best results, being careful to treat under covering objects under which the ants might nest.

Carpenter Ant

Even if the nest has been located within a structure and treated, it is important in wooded areas to treat the outer perimeter in order to prevent reinfestation. Dead wood that might be such a source for reinfestation should be removed, including dead branches and limbs on nearby trees.

Otherwise, spray window sills and roof shingles. Dust or spray the subarea and the outside of the foundation. Spray wood piles, trash piles, and around tree stumps.

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CHAPTER 12

HONEY BEES

Eric C. Mussen[1]

INTRODUCTION

Although honey bees are familiar to everyone, they were imported into what now are the Americas from the middle 1600s to the early 1900s. Most of the importations, and all of the stocks that persisted, were from Europe (EHBs) and northern Africa. Honey bees now can be found in hives managed by hobby or commercial beekeepers, or living on their own, in locations that provide adequate forage and shelter, including voids in buildings and dense vegetation, as well as in hollow trees. Honey bees pollinate flowers and produce honey. Most adults know that honey bees sting and, therefore, fear them. One of every one hundred or so individuals swells significantly when stung and considers him- or herself to be "allergic." Truly hypersensitive individuals, who develop potentially life threatening anaphylaxis after being stung, number only one or two per thousand people. The arrival of Africanized honey bees (AHBs – an experimental cross of European and central African stock) from South America changed the complexion of potential bee-human or bee-animal interactions. AHBs tend to become disturbed at the nesting site more easily then EHBs, they react more quickly, and many more bees are apt to fly out and sting. AHBs also follow a "marked" (stung) target much further away from the hive then EHBs.

BIONOMICS
(Figure 12-1)

Nearly everyone recognizes a honey bee by sight. It is about 0.5 in. (12.7 mm) long, fairly robust, and has a brown or black background color that is covered with think masses of hair which impart a striped appearance. Honey bees can survive only within colonies having a long-lived queen (up to five years) and at least 4,000 workers. All aspects of honey bee life (brood rearing, food storage) in the nest are conducted in or on the combs that are built from wax secreted by worker abdominal glands. Given enough nectar, combs can be built remarkably quickly. A healthy colony is perennial, with the total population usually fluctuating from a low of 10,000 to 15,000 in the winter to a high of 45,000 to 60,000 in the summer. Due to their ability to create heat from carbohydrate metabolism (honey) and cool the nest with evaporative cooling (using water), honey bees can tolerate nearly every microclimate in California and are found almost everywhere, except on tops of the highest mountains. Colonies reproduce by swarming when the old queen and half the workers fly off to start a new colony. The original colony completes rearing a replacement queen. Reproductive swarms issue from EHB colonies once a year (March to June), while AHB colonies can swarm up to six times a year. A swarm in flight is a huge whirling (scary to many) mass of bees. Usually the new hive location has not been determined before the swarm leaves. The bees form a cluster on some object and remain in the cluster until a new nesting location is found (usually between a few hours and a few days later). Bees in a cluster normally are not defensive unless they are physically molested, so they pose little threat to nearby people or pets. If the urge to start building combs becomes overwhelming, they start building on the spot. Once the bees have started building comb, they become defensive of their nest. A similar looking cluster can form when AHBs abscond (all get up and go together) due to lack of food or continual disturbance. That type of cluster is much more likely to respond defensively to minor stimulation.

Queen bees lay 1,000 to 2,000 eggs per day. The eggs hatch in three days and the larvae are fed "royal jelly," pollen, and nectar until they pupate. European

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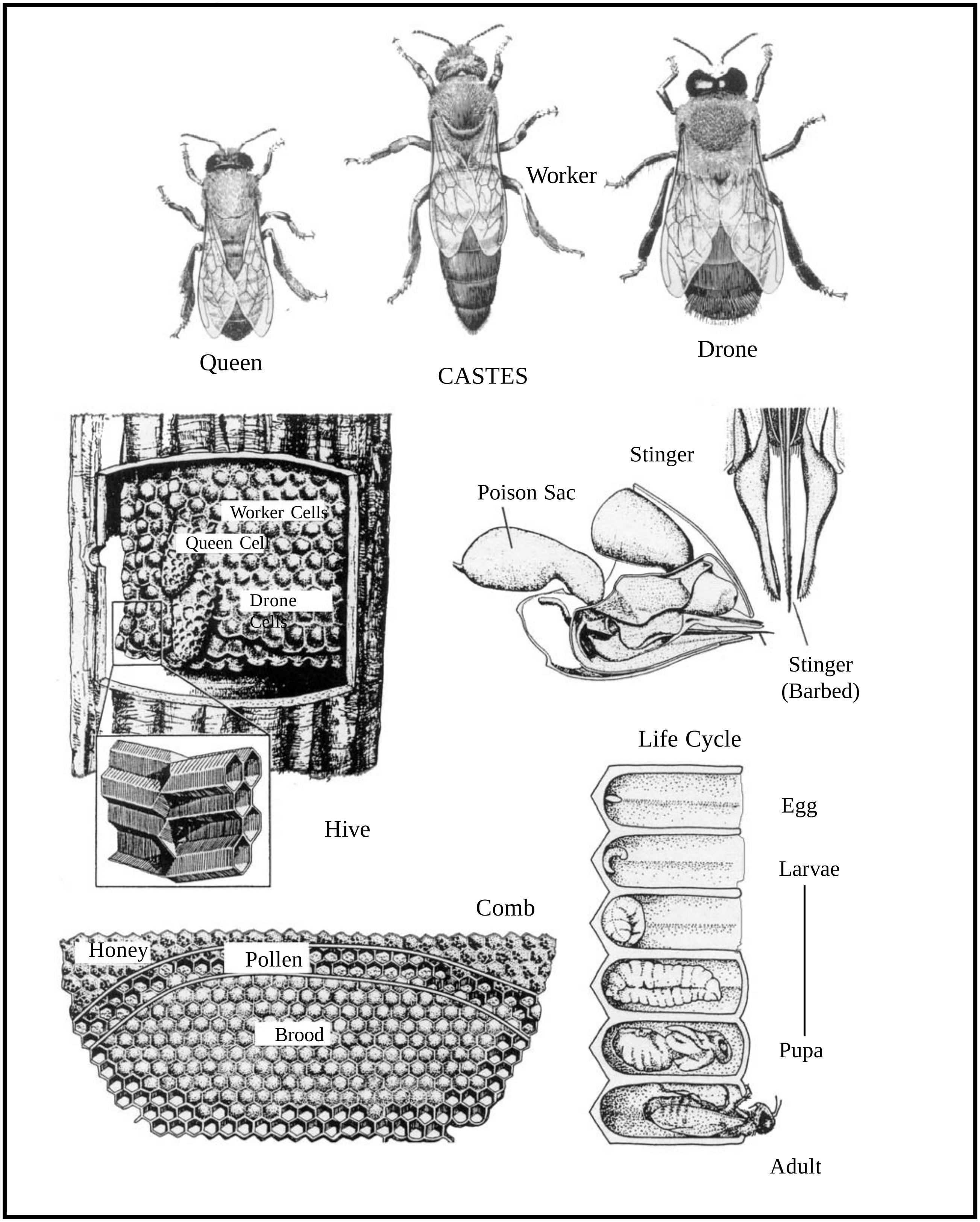

Figure 12-1. Honey Bee (*Apis millifera) (*courtesy Winston, *Biology of the Honey Bee,* 1987).

queens emerge in 16 days, drones in 24 days, and workers in between, 21 days. Africanized queens and workers are quicker (15 and 18.5 days, respectively). AHB drones still require 24 days to become adults.

Honey bees fly only during daylight hours, when temperatures reach 13°C (55°F), there is no rain and winds are below 19 kph (12 mph). They defecate only in flight and leave tan colored spots and streaks (full of pollen when examined microscopically) on any object in the area. For this reason and the fear of bees, many municipalities have a nuisance ordinance allowing them to evict bees upon complaint.

CLASSIFICATION

Bees belong in the Order Hymenoptera, Suborder Apocrita, Superfamily Apoidea, and Family Apidae. There are three genera and 54 species of bees in North America, and California has three genera and 28 species. In the Subfamily Apinae, California has only one genus and species, *Apis mellifera*, the honey bee. It can be distinguished from other social bees by their vestigial maxillary palpi and absence of hind tibial apical spurs. Presently we have three major races in California: *Apis m. ligustica* (Italian), *A. m. caucasica* (Caucasian), and *A. m. carnica* (Carniolan). Other races include, *A. m. mellifera* (German black), *A. m. lamarkii* (Egyptian), and the hybrids that occur with European races crossed with *A. m. scutellata*; and their abundance is expected to increase for many years. These races and crosses are somewhat distinguishable by morphological characters. However, CDFA is relying on mitochondrial DNA analysis to determine whether a specimen worker bee has "sub-Saharan" genes and officially can be designated "Africanized." Overall, EHBs are slightly larger than AHBs and can be separated with about 60 percent certainty by the FABIS (Fast Africanized Bee Identification System) that measures wing length of an average of 10 individuals.

MEDICAL IMPORTANCE

Most female hymenopterans have an ovipositor that has been modified to puncture something. Parasitic species either attach to the host directly or insert eggs into the host's habitat. Predators use their sting and venom to overcome prey. Since nearly all bees live on nectar and pollen, the portion of the ovipositor dedicated to stinging now serves solely as a defensive tool. Honey bee stings are unique because they have barbs that become embedded in the tissue that is stung. When the bee leaves, the sting is pulled from her abdomen, including the sting shaft, venom sac, parts of the abdominal exoskeleton, muscles, and nerves. This allows the severed organs to continue working the sting deeper into the flesh and delivering more venom into the wound for about two minutes. If stung, it is best to scrape the sting off as soon as possible. The sting complex also bears the organ that produces "alarm pheromone." That odor induces other bees to sting in the same vicinity. AHBs will follow a "marked" individual up to a quarter mile (0.4 km) to deliver a sting, while EHBs usually quit between 50 and 100 ft. (15-30 m) from the hive.

The most biologically active compounds of honey bee venom are the enzymes hyaluronidase and phospholipase and the peptide melittin. The enzymes help the venom spread through the tissues, and melittin causes the pain associated with stings. Usually a single sting induces a sharp, burning pain that subsides into a persistent ache. The tissue swells and is tender to the touch for a couple days. In hypersensitized individuals, the enzymes can bring on anaphylactic shock. Lowered blood pressure and impaired respiration can lead to death in minutes. Injected epinephrine usually relieves the symptoms rapidly.

In a number of cases, deaths have resulted from a relatively small number of honey bee stings in elderly men, most of whom had cardiopulmonary problems. Even though melittin releases histamine, serotonin, and other vasoactive compounds from human mast cells, analysis of blood samples determined that heart attacks, not anaphylaxis, were the cause of death.

Animals can die of massive envenomation. It is estimated that the LD_{50} for a healthy human is about 2.8 mg/kg (8.6 stings/lb). This is around 200 to 500 stings per child and over 1,100 per adult. The consequences of such envenomation, and its treatment, can be found in the references. However, it should be emphasized that lives have been lost days after medical treatment eliminated all evident symptoms of multiple-sting events. The enzymes in the venom continued to break down tissues in the patient. The damage, plus the accumulation of tissue debris in the kidneys, led to death by "organ failure." Medical observation (blood tests) should continue for many days following a bad stinging event, by either bees or wasps.

MANAGEMENT AND CONTROL

Currently, we know of no way to prevent AHBs from spreading to their ecological limits. Any global control measures directed at honey bees as an organism would also eliminate EHBs, upon which we rely for approximately one-third of our daily diet (crop pollination of fruits and vegetables). Efforts should be made by the general public to reduce or prohibit access to potential nesting sites. Swarms should be destroyed before they have a chance to find new nesting locations and become established. Newly established colonies should be removed before they increase in size and become unmanageable. Homeowners should be discouraged from trying to remove the colonies themselves. Government agencies sometimes provide such services for an interim period; but as colony numbers explode, local entrepreneurs provide relief.

Anyone contemplating direct contact with AHBs must obtain appropriate equipment for handling bees and wear protective clothing. Easily accessible clusters may be soaked in substantial volumes of water containing M-pede®, an insecticidal soap that drowns the bees as more water is sprayed on them after they have been knocked to the ground (keep in touch with California Department of Pesticide Regulation for current registrations). Bees in walls, ceilings, under floors, down chimneys, etc. should be removed by professional pest control operators or by individuals specially licensed and bonded for bee removal work (consult the Yellow Pages). Also, the county agricultural commissioner's office, local farm advisor, or local bee club often has a list of beekeepers who are willing to respond to bee related concerns. There usually is a charge for the service and the charge is proportionately higher if the bees are in the wall. All feral colonies in areas where AHBs exist will be suspect AHBs, so beekeepers should not be hiving swarms, or bees removed from buildings, where AHBs are present. Bee removals must include extraction of combs of brood and honey to prevent damage by rotting brood and seeping honey. Bee removals must be completed by thorough sealing of all openings in that area of the building to prevent reinfestation by the next swarm attracted to the odor of the former occupants.

Municipal, county, and other governmental agencies should decide among themselves who will be responsible for retrieving swarms, removing established colonies from outdoor and structural locations, and who will respond to emergency calls about stinging episodes. Those decisions should be well disseminated, so that the general public knows immediately whom to contact for assistance.

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CHAPTER 13

INSECTS OF MINOR PUBLIC HEALTH SIGNIFICANCE

Lal S. Mian[1] and Major S. Dhillon[2]

The forgoing sections of this training manual deal with information on major insects that play a significant role in disease transmission and/or cause direct injury through biting and stinging. In class Insecta, there are still other insects that may affect public health directly or indirectly through biting activity, body parts, bodily secretion, or their biomass causing public discomfort and nuisance. To complement the role of insects in public health, it is germane to include information on all insects of major and minor importance, whether capable of disease transmission or causing injury or discomfort. Therefore, the available information on all taxa of minor public health importance, as summarized in TABLE 13-1, is presented here in a phylogenetic order.

SUBCLASS: APTERYGOTA

This primitive group includes wingless insects, which undergo little or no metamorphosis. They have chewing (mandibulate) type mouthparts. In this group, two orders namely, Collembola and Thysanura are briefly discussed in regard to their public perception as nuisance insects.

ORDER: COLLEMBOLA - Springtails
(*Coll* = glue; *embola* = bolt or wedge - collophore)

General Description

Collembolans are minute insects that have a forked structure (furcula) under the abdomen which aids them in jumping, hence they are commonly known as springtails (Fig. 13-1: 1). They are 0.1 to 0.2 in. long and capable of jumping 3 to 4 inches. Springtails also possess on the underside of the abdomen (1st segment) a structure called collophore which is believed to be used in water uptake. In body coloration, springtails vary from white, gray and yellow to orange, green and red. Springtails vary in food habits from saprophagous (decaying organic matter feeders) to occasionally phytophagous (plant feeders). They live in concealed places in the soil, under bark, decaying logs, leaf-cover, and in fungi. They may be found in high numbers on the surface of fresh water ponds, pools, along the seashore, on vegetation, in termite nests, caves, and snow fields (commonly mistaken as snow fleas). Their numbers could be judged from 1,000 sq. ft. to millions per acre of soil surface.

Importance

Due to their presence in high numbers in a variety of habitats, such as swimming pools and snowfields, springtails could become a source of public nuisance, causing occasional public complaints.

ORDER: THYSANURA - Bristletails
(*Thysan* = bristle, *ura* = tail)

General Description

The bristletails are small to medium-sized insects, 0.3 to 0.8 inches in length. They have elongated bodies with three tail-like appendages (two cerci and a median caudal filament) at the posterior end of the body (Fig. 13-1: 2). They have long thread-like antennae with chewing type mouthparts. The tarsi are 2 to 3 segmented. The abdomen is 11 segmented and the body covered with scales.

This order is divided into four families, namely, Machilidae, Lepidotrichidae, Lepismatidae, and Nicolitiidae.

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[2]Northwest Mosquito and Vector Control District, 1966 Compton Ave., Corona, CA 92881-3318.

TABLE 13-1. Phylogenetic list of other insects [3/] of public heath importance.

Order	Family	Common Name	Scientific Name	Importance
Collembola	Several	Springtails	Several spp.	Public nuisance.
Thysanura	Several	Bristletails		Public nuisance.
		1. Silverfish	*Lepisma saccharina*	
		2. Firebrats	*Thermobia domestica*	
Ephemeroptera	Several	Mayflies	Several	Public nuisance.
Orthoptera	Gryllidae	Crickets	*Acheta domestica*	Public nuisance.
Dermaptera	Forficulidae	Earwigs	*Forficula auricularia*	Pinching and secretion of a foul smelling yellow brown liquid.
Psocoptera	Liposcelidae	Psocids	Several spp.	Generally public nuisance, some
		Common book louse	*Liposcelis divinatorius*	species act as intermediate hosts for the sheep tapeworm.
Thysanoptera	Thripidae	Thrips	Several spp.	Occasional biting.
Hemiptera	Notonectidae	Backswimmers	Several spp.	Biting if handled.
	Belostomatidae	Giant Water Bugs	Several spp.	Biting if handled.
	Pentatomidae	Stink Bugs	Several spp.	Disagreeable odor.
Homoptera	Cicadellidae	Leafhoppers	Several spp.	Sharp pinching.
	Aphididae	Aphids	Several spp.	Public nuisance.
Coleoptera	Carabidae	Ground Beetles	Several spp.	Secretion of skin irritating substance.
	Staphylinidae	Rove Beetles	Several spp.	Biting and transmission of pathogens via feces and crushed bodies.
	Dermestidae	Skin Beetles	Several spp.	Nuisance; body hairs causing allergies.
	Tenebrionidae	Darkling Beetles	Several spp.	Intermediate hosts for Helminthes (worms); emission of foul smelling liquid when touched.
	Meloidae	Blister Beetles	Several spp.	Body secretions causing skin blisters.

Continued on next page

TABLE 13-1 - continued

Order	Family	Common Name	Scientific Name	Importance
Trichoptera	Several	Caddisflies	Several spp.	Nuisance; causing allergies through body scales.
Lepidoptera	Arctiidae	Tiger Moths	Several spp.	Same as above.
		Hickory Tussock Moth	*Halisidota caryae*	Same as above.
	Lymantriidae	Tussock Moths	Several spp.	Same as above.
		Gypsy Moth	*Porthetria dispar*	Same as above.
		Brown Tail Moth	*Nygmia phaeorrhoea*	Same as above.
		Douglas Fir Tussock Moth	*Hemerocampa pseudotsugata*	Same as above.
		White-marked Tussock Moth	*H. leucostigma*	Same as above.
	Lasiocampidae	Tent Caterpillar	Several spp.	Same as above.
		Eastern Tent Caterpillar	*Malacosoma americanum*	Same as above.
		Forest Tent Caterpillar	*M. disstria*	Same as above.
	Saturniidae	Giant Silk Moths	Several spp.	Same as above.
		Io Moth	*Automeris io*	Same as above.
		Buck Moth	*Hemileuca maia*	Same as above.
	Nymphalidae	Mourning Cloak	*Nymphalis antiopa*	Larval stinging hairs causing dermatitis.

[a/]Other than insect taxa of major public health importance, such as Dictyoptera (Blattidae), Hemiptera (Cimicidae and Reduviidae, *Triatoma* spp.) Anoplura, Siphonaptera, Diptera, and Hymenoptera.

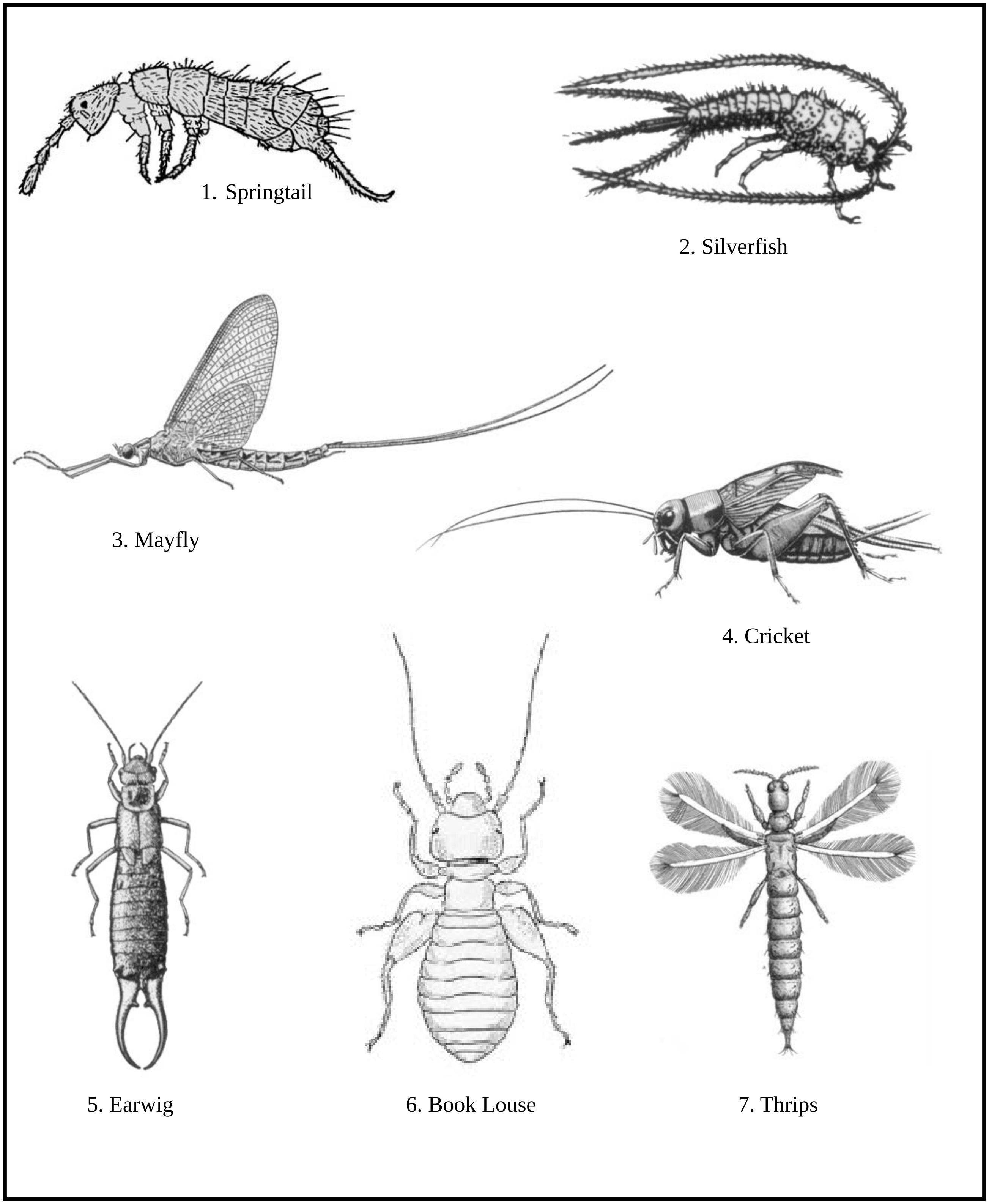

Figure 13-1. Miscellaneous insects of public health importance (courtesy Pictorial Keys, CDC, 1966; and Hogue and Powell, *California Insects*, 1987).

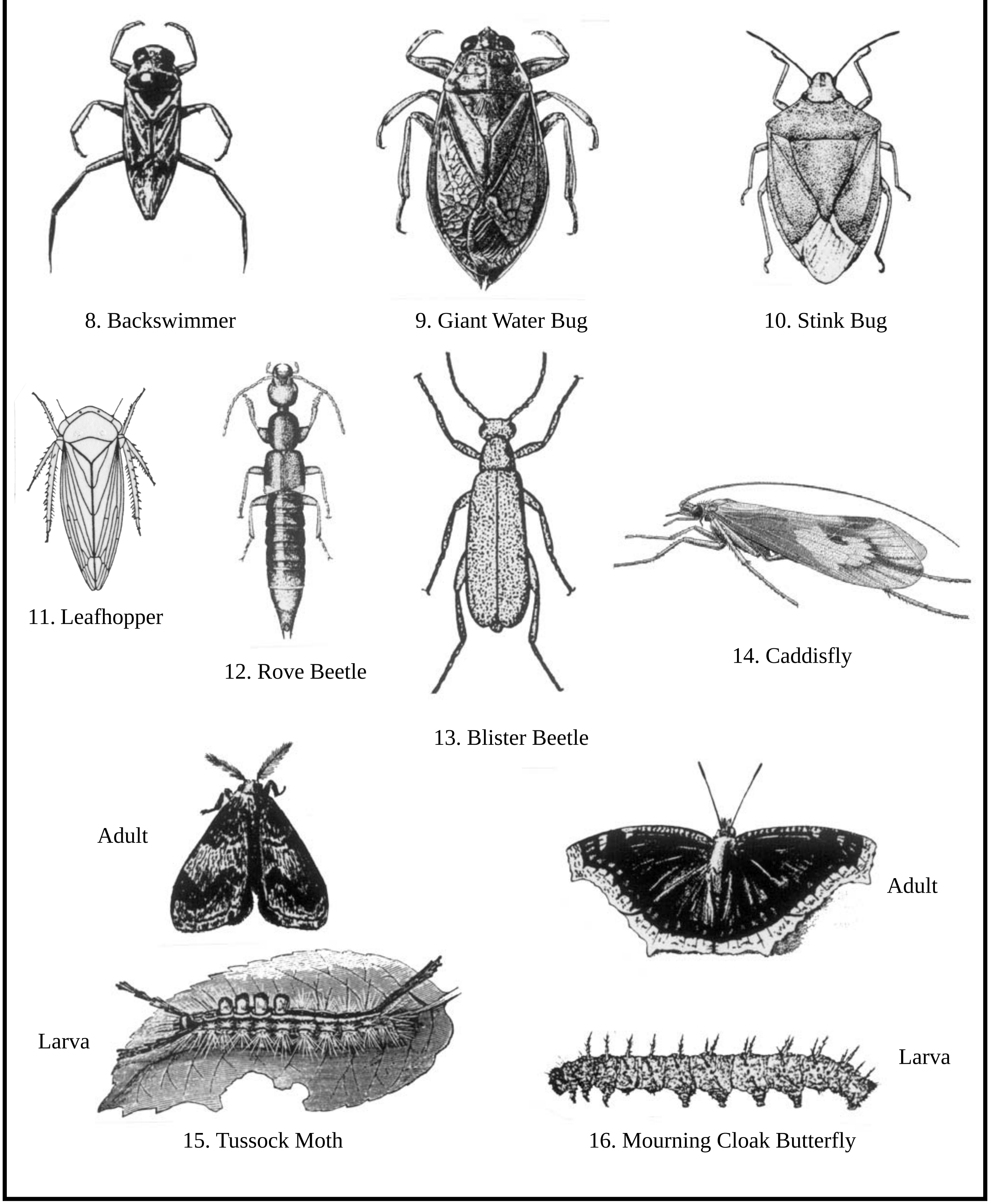

Figure 13-1. Continued

Importance

Of the four families, only Lepismatidae have two of its species that can be found inside buildings. These include the Silverfish, *Lepisma saccharina* Linnaeus, and the firebrat, *Thermobia domestica* Packard. The former species is gray in color and about 0.5 inch in body length; it is found in cool and damp sites. The latter is tan to brown in color and about the same size as the silverfish; it is found in warm spots around furnaces, broilers, and steam pipes. These insects feed on all sorts of starchy materials, such as book bindings, starched clothing, linens, curtains, silk, and wallpaper. Infestations of these insects are considered as nuisances to the homeowners.

SUBCLASS: PTERYGOTA

The Pterygota include all those insects which undergo complete (egg, larva, pupa, and adult) or incomplete (egg, nymph, and adult) metamorphosis. Only those pterygote orders that have some public health importance will be discussed here, such as Ephemeroptera, Orthoptera, Dermaptera, Psocoptera, Thysanoptera, Hemiptera, Homoptera, Coleoptera, Trichoptera, and Lepidoptera.

ORDER: EPHEMEROPTERA - Mayflies
(*Ephemero* = short-lived; *ptera* = wings)

General Description

Mayflies are small to medium sized insect, 0.3 to 0.8 in. in length. They are soft-bodied and possess two to three long tails (bristles). The adults have two pairs of membranous wings with intricate venation (Fig. 13-1: 3). The forewings are large and somewhat triangular, whereas, the hind wings are smaller and rounded or may be vestigial or wanting in some species. Wings are generally held upright when at rest. The immatures (nymphs) are found in a variety of aquatic habitats. The nymphs possess leaf-like gills (breathing organs), both on the abdomen and thorax. Older nymphs, when ready to emerge as adults, come up to the water surface. The freshly molted winged adult (called sub-imago) flies a short distance to the shore and molts one more time before becoming the adult mayfly. Adult mayflies cannot feed due to the lack of functional mouthparts. They are short-lived (1 to 2 days), whereas, the aquatic nymphal stage takes almost a year to develop to the adult stage. Adult mayflies, especially the males, often swarm; individual females entering the male swarm start mating with the males still on wing. Eggs are laid on the water surface or attached to aquatic vegetation or rocks.

The North American mayflies are divided into 15 families and 41 genera. The three large families are Baetidae, Ephemeridae, and Heptageniidae.

Importance

Ecologically, both mature and immature mayflies are important in the food chain. The immatures make a good source of food for fish, whereas, the adults are consumed by birds, amphibians, spiders, and other predaceous arthropods. From the standpoint of human health and comfort, however, adult mayflies in enormous numbers near river fronts, lakes, etc., may pile up to such an extent that they create a nuisance or health and safety concerns.

ORDER: ORTHOPTERA
(*Ortho* = straight; *ptera* = wings)

General Description

The order Orthoptera contains a large number of well-known insects, such as grasshoppers, mantids, crickets, walking sticks, etc. In general characters, orthopterans have four wings with the front ones leathery in texture (tegmina). The hind wings are large and membranous with many veins and held beneath the front wings when at rest. These insects have chewing type mouthparts and one pair of antennae. They have mostly elongated bodies with a pair of cerci and in the females an ovipositor at the posterior end.

From the standpoint of public health, the information on crickets is briefly presented here.

Family: Gryllidae - Crickets

General Description

Crickets have long thread-like antennae and their hind legs are modified for jumping (saltatorial type). The sound producing stridulating organ is situated on the front wings of the males with the auditory organ (tympanum) on the front tibiae. The ovipositor in female crickets is cylindrical. The adult females lay eggs in the ground or in vegetation.

There are eight subfamilies in this group and discussion is limited to the subfamily Gryllinae, which includes both the house cricket and the field cricket (Fig. 13-1: 4). These insects are about an inch in body length and vary in color from brown to black. The house cricket, *Acheta domestica* L., enters homes, whereas, the field cricket, *Gryllus pennsylvanicus* (L.), is an outdoor species common in pastures, meadows, fields, and roadside areas.

Importance

Apart from feeding on various items in the house, these insects are well-known songsters and may be annoying.

ORDER: DEMAPTERA - Earwigs
(*Derma* = skin; *ptera* = wings)

Earwigs are slender-bodied insects with forceps-like cerci (Fig. 13-1: 5). They have four wings; the front wings are short and leathery, whereas, the hind wings are membranous with veins and folded under the front wings. They have chewing type mouthparts and filiform antennae that are as long as the head and thorax together. The tarsi are three segmented. The females lay eggs in the ground and guard them. Earwigs overwinter as adults. During the day they hide in cracks, crevices, and under bark. They are generally scavengers but occasionally may become herbivorous.

The order Dermaptera is divided into three suborders, namely, Arixenina, Diploglossata, and Forficulina. Unlike the latter, members of the former two suborders have small cerci, which are not forceps-like.

The Forficulina are found in this country and need to be briefly discussed. This suborder is divided into four families; Chelisochidae (one sp.), Forficulidae (two spp.), Labiduridae (three genera), and Labiidae (several genera).

Importance

The name "earwigs" goes back to an old superstition that these insects could invade people's ears; this is not true. Earwigs are scavengers and may sometimes feed on plants. They do not bite people, but if handled they may pinch with their cerci. The males of larger earwigs can inflict a painful pinch. Some species possess scent glands dorsally on the 3rd and 4th abdominal segments. From these glands they can squirt a foul smelling yellow brown liquid over 3 to 4 inches.

ORDER: PSOCOPTERA - Psocids
(*Psoco* = rub small; *ptera* =wings)

General Description

The psocids are small (mostly < 0.2 in.) soft-bodied insects. They may be winged or wingless. The winged psocids have two pairs of membranous wings with the hind pair usually smaller or in some cases vestigial. These insects have chewing (mandibulate) type mouthparts with the clypeus somewhat swollen. They have long antennae and 2 or 3 segmented tarsi. The psocids undergo incomplete metamorphosis with six nymphal instars. The eggs are laid singly or in clusters often covered in silk. These insects feed on molds, cereals, pollen, and dead insect parts. Some of the psocids (wingless species) could be found inside homes, whereas, a majority of these (winged species) are found outdoors, usually under the bark or foliage of trees and shrubs, hence the name bark lice.

The psocids known in the U.S. represent 150 species, 40 genera, and 11 families. The largest family is Psocidae, which consists of over 40 species of the common bark louse. The common book louse, *Liposcelis divinatorius* Muller (Fig. 13-1: 6), an indoor species, belongs to the family Liposcelidae. This species lives in cracks, crevices, behind loose wall paper, among books or paper, and can be recognized by its enlarged femora.

Importance

Psocids, whether bark lice or book lice, do not feed or parasitize on humans; however, their mere presence (especially book lice) may frequently pose a nuisance. However, certain species in the genus *Liposcelis* and *Rhyopsocus* have been found to act as intermediate hosts of the fringed tapeworm of sheep, *Thysanosoma ostinoides* Diesing.

ORDER: THYSANOPTERA - Thrips
(*Thysano* = fringe, *ptera* = wings)

General Description

Thrips are small (<0.3 in.), slender, and soft-bodied insects with a conical head. They may be winged or wingless. The winged thrips have two pairs of typical wings that are narrow and veinless with fringes of long hairs around the margins (Fig. 13-1: 7). Thrips have lacerating- sucking type mouthparts. They are unique insects in that their mouthparts are asymmetrical, the proboscis is composed of three stylets; two maxillary and one mandibular, with the right mandible lacking. The antennae are 4 to 9 segmented; the tarsi 1 to 2 segmented and 1 to 2 clawed. In some species the ovipositor is well-developed, in others the last abdominal segment appears tubular. The metamorphosis in thrips is almost complete. Depending upon the species, the first two feeding instars (larvae) are wingless, whereas, the third and fourth or even fifth instars (non-feeding) are called prepupae and pupae. The winged females lay their eggs in plant tissues or deposit them in cracks and crevices in the bark of trees. Thrips are multivoltine having several generations per year.

The order Thysanoptera is divided into two suborders: Terebrantia (with ovipositor) and Tubilifera (with tubular abdominal tips). The North American thrips are placed into five families, the largest of which is Family Thripidae containing almost all common species of thrips.

Importance

Thrips are phytophagous (plant feeding) insects attacking flowers, leaves, fruit twigs, or even buds of a wide variety of plants. Not only do they damage plant tissues by their feeding, they are the vectors of a number of plant diseases, especially viral diseases. However, sometimes these insects occur in huge numbers and can land on humans. They can bite humans with their lacerating mouthparts causing itching of the skin.

ORDER: HEMIPTERA - Bugs
(*Hemi* = half; *ptera* = wings)

General Description

The members of this order are called true bugs. They may be winged or wingless. The winged forms have two pairs, the front of which is half leathery at the base and half membranous and veined at the tip. The hind pair of wings is membranous. These bugs have piercing-sucking type mouthparts with the beak (proboscis) projecting backward ventrally (opishognathus) between the coxae. The segmented beak is composed of four stylets (two mandibular and two maxillary) and is kept in a groove in the labium when at rest. The hemipterans have long four-segmented antennae. There are aquatic and terrestrial forms. They are mostly phytophagous, sucking the sap from a variety of natural and cultivated plants. Some are predaceous on other insects, whereas, others attack man and animals.

The order Hemiptera is a fairly large group that is divided into 3 suborders and 44 families. Members of a number of taxa that have bitten humans accidentally, include backswimmers (Notonectidae), creeping water bugs (Naucoridae), giant water bugs (Belostomatidae), water scorpions (Nepidae), big-eyed bugs and chinch bugs (Lygaeidae), wheel bugs and the masked hunters (Reduviidae), and the stink bugs (Pentatomidae). Of these, only Notonectidae, Belostomatidae, and Pentatomidae are discussed here.

Family: Notonectidae - Backswimmers

General Description

These insects are about 0.5 inch long and swim upside down in aquatic habitats. They possess swimming (natatorial) type legs with the hind legs functioning like oars (Fig. 13-1: 8). There are two genera in this group.

Importance

The backswimmers are predaceous on other small arthropods by sucking their body fluid. These insects will bite man if handled; the effect is much like a bee sting.

Family: Belostomatidae - Giant Water Bugs

General Description

Some members of this group are the largest (2 in.) bugs in the Order Hemiptera. They are generally brownish, oval, and somewhat flattened in appearance. The front legs are raptorial used in grasping the prey (Fig. 13-1: 9). These bugs are aquatic but they frequently come out of the water flying to lights at night, hence the name “electric light bugs.” The eggs are laid at the bottom of ponds or on aquatic vegetation; or in some species the eggs are laid on the back of the males, who carry them until they hatch into nymphs.

There are three genera known from North America.

Importance

The giant water bugs feed on small insects, snails, tadpoles, or even small fish. These insects will inflict a painful bite if handled carelessly.

Family: Pentatomidae - Stink Bugs

General Description

This is a large group of medium sized (0.5 in.) insects that are easily distinguished by their shield-like appearance and five-segmented beak (Fig. 13-1: 10). They are brightly colored and conspicuously marked. These insects emit a disagreeable odor. The females lay the barrel-shaped eggs in clusters.

Importance

Of the three subfamilies, the Pentatominae are phytophagous, whereas, Acanthosomatinae and Asopinae are predaceous on other insects. The odor produced by these insects is disagreeable.

ORDER: HOMOPTERA - Homopterans
(*Homo* = alike; *ptera* = wings)

Closely related to order Hemiptera, this order contains a large number of diverse species. They vary considerably in size and body color. Their life cycle is complex involving both bisexual and parthenogenetic generations of winged and wingless individuals in many species. Like hemipterans, the homopterans have piercing-sucking mouthparts. They feed on a wide variety of plants.

The order is divided into two suborders: Auchenorrhyncha (15 families) and Sternorrhyncha (17 families). The two families that need to be discussed here include Cicadellidae (from Auchenorrhyncha) and Aphididae (from Sternorrhyncha).

Family: Cicadellidae - Leafhoppers

General Description

Also called jassids (Jassidae), this is a large group the members of which vary in color, size, and form. They can be easily recognized by the presence of one or more rows of small spines along the hind tibiae (Fig. 13-1: 11). They are usually <0.5 inch long with a large number of them having beautiful color patterns. There are some 2,500 species in North America.

Importance

The jassids or leafhoppers feed on a variety of plants and are vectors of important viral diseases of plants. Some species are attracted to lights at night and occasionally land on humans and may inflict a sharp and irritating pinch on exposed body parts.

Family: Aphididae - Aphids

General Description

Also called Aphidae, these insects are small and soft-bodied. They can be recognized by their pear-shaped bodies with two tube-like structures (cornicles) at the posterior end of the abdomen. They have long antennae and two pairs of membranous wings in the winged forms. They have an unusual complex life cycle. The winged females lay their eggs on the bark of twigs or trunk of deciduous host trees. The overwintering eggs hatch into nymphs in the spring. They feed on sprouting buds of the host plants and grow into adult females migrating to leafy plants. During the summer, these wingless females produce many parthenogenetic generations of wingless females. By fall, they start producing winged females and males who migrate back the winter host(s) where the females lay overwintering eggs.

Another peculiarity about aphids is that they have a filter-type stomach. The function of which is to filter out all simple sugars from the plant sap to the hind gut and squirted out as honey dew.

Importance

Aphids feed on a variety of plants, from ornamentals, vegetables, to crop plants and shade trees. When they are produced in such high numbers that their bodies or body parts can be occasionally blown into nostrils and eyes and accidentally inhaled. Some species, such as the giant bark aphid, produces so much honey dew that it attracts a large number of muscoid flies, which may create a nuisance

ORDER: COLEOPTERA - Beetles
(*Coleo* = sheath; *ptera* = wings)

General Description

As the largest order of the class Insecta, its members vary greatly in size, ranging from <0.1 to 2 inches in body length. They vary from dull gray, brown, and black to metallic black, blue, green, and red. They have two pairs of wings; the front wings (elytra) are leathery, thickened, and hard. The hind membranous wings folded under the front wings, are used in flight. In some species, the front and hind wings may be reduced. These insects have chewing mouthparts with well-developed mandibles. The front of the head of weevils is prolonged into a snout bearing mouthparts at the anterior end. Coleopterans undergo complete metamorphosis. Depending on the species, they may have one or more generations per year (uni- or multivoltine).

Beetles may be found in a variety of habitats, from aquatic and semiaquatic to terrestrial. They also vary greatly in their ecological niche, from epi- and endo-phytophagous, commensal, and predaceous to detritus feeders or scavengers.

As the largest insect order, Coleoptera represents about 40 percent of all described insect species, roughly equal to a quarter million species! About 30 percent of these insects are found in the United States. The order is divided into four suborders; Archosternata, Adephaga, Myxophaga, and Polyphaga, with 111 families. However, only the pertinent families belonging to suborders Adephaga and Polyphaga will be discussed.

SUBORDER: ADEPHAGA

The members of this suborder have the hind coxae divide the first abdominal sternite with the posterior margin of the sternite not meeting across the middle. These insects have filiform antennae, and a tarsal formula of 5-5-5 (fore, middle, and hind tarsi 5 segmented). They are mostly predaceous insects. This suborder has eight families, of which Carabidae is briefly discussed.

Family: Carabidae - Ground Beetles

General Description

Ground beetles are medium-sized insects (0.3-0.8 in.) with dark, shiny, striated elytra. The prothorax and head gradually narrow down from the abdomen. These insects are more active at nighttime (nocturnal). During the daytime, they can be commonly found under bark, rocks, stones, leaves, soil burrows, and other debris.

Carabidae is considered to be the second largest family of beetles in North America comprising of 2,500 species.

Importance

Both the adults and larvae are predaceous on other small arthropods. The bombardier beetles eject a glandular fluid, which can cause skin irritation in some people.

SUBORDER: POLYPHAGA

The members of this group are differentiated from other beetles by having the first visible abdominal sternite not divided by the hind coxae, extending the posterior margin completely across the first abdominal segment. They vary greatly in the types of antennae and the tarsal formula.

The families of public health importance include Staphylinidae, Dermestidae, Tenebrionidae, and Meliodae.

Family: Staphylinidae - Rove Beetles

General Description

These are small to medium-sized insects (0.3-0.8 in.) insects with slender elongated bodies. They are usually black or brownish in general body coloration. They can be easily recognized by their very short elytra, which leave over one half of the abdomen exposed (Fig. 13-1: 12). The hind wings are well-developed and folded under the elytra. They have chewing mouthparts with long sharp mandibles.

They are found in a variety of habitats, such as decaying organic material (dung and carrion) under stones, along the shores of streams, in fungi, leaf-litter, nests of birds, rodents, ants, and termites.

Staphylinidae is considered to be the largest family of beetles with 2,900 North American species.

Importance

Adults and larvae of most rove beetles are predaceous on other insects. However, those species that visit dung or carrion may become a source of infection and pathogenic inocula via their feces or dead or crushed bodies. Moreover, some large rove beetles, with their long and sharp mandibles, can inflict a painful bite when handled carelessly.

Family: Dermestidae - Skin Beetles

General Description

The dermestids are small to medium sized insects

(0.3-0.8 in.) ranging in body shape from oval to convex and oblong. The body color varies from black to dull gray or brown with characteristic patterns. Their bodies are covered with scales or hairs. The larvae of dermestids are very hairy and they are more destructive than the adults.

This group contains many species of significant economic importance, such as carpet beetles, granary beetles, and others.

Importance

Both adult and larval dermestids feed on a variety of plant and animal products, including skin, fur, wool, silk, rugs, leather, stored foods, and carrion. Some dermestids found in/on carpets and clothing in the home environment may be a source of allergens through their cast skin or body hairs, thus, causing dermatitis and other allergic reaction in sensitive individuals. They can cause significant damage to insect (arthropod) collections in museums.

Family: Tenebrionidae - Darkling Beetles

General Description

This is a large group of black to brownish looking and small to medium-sized insects (<0.3-0.8 in.). They have 11-segmented antennae with notched eyes and a tarsal formula of 5-5-4. Like the ground beetles, the darkling beetles may be found under rocks, bark, rubbish, and in fungi. They feed on plant materials, including stored food products.

Tenebrionidae is a large family with 1,400 North American species.

Importance

Most of the tenebrionids are plant feeders. However, some of the important stored product insects, such as *Tribolium confusum* du Val, has been known to act as intermediate host for the Helminths, *Hymenolepis diminuta* and *Hymenolepis nana*. Infection occurs when the intermediate hosts(s) infected with cysticercoids is ingested. Of other tenebrionids, some species in the genus *Eleodes* emit a disagreeable fluid when handled. Moreover, adults of the lesser mealworm, *Alphitobius diaperinus (*Panzer*)*, breeding in chicken manure at commercial poultry ranches in southern California, are attracted to light at night and can become a public nuisance.

Family: Meloidae - Blister Beetles

General Description

Most of the blister beetles are long, narrow and cylindrical in shape; they measure 0.3-1.0 inch in length. They vary in color from black to dark bluish (sometimes with a purplish tint). The pronotum in these insects is narrower than the head or elytra (Fig. 13-1: 13).

Some species, such as in the genus *Epicauta*, undergo a complex complete metamorphosis (hyper-metamorphosis) in which the seven larval instars are quite different. The first instar is active with long legs (triungulin); the second instar similar to the first except for shorter legs; the third, fourth, and fifth become thicker and look scarabaeiform; the sixth instar is darker with a thick exoskeleton without the functional legs (coarctate type), which usually hibernate; and the seventh is small, active, white, and legless (non-feeding) that soon pupates.

Importance

Several species in the larval form feed on the eggs of grasshoppers, honey bees, or on the food stored with eggs in the cells of honeycomb. These insects are mostly plant feeders in the adult stage. Adult blister beetles contain cantharidin in their body-fluid that often causes blisters. Cantharidin extracted from the body of the European blister beetle (Spanish fly), *Lytta vesicatoria* L., is believed to be an aphrodisiac. Cantharidin has a penetrating action and can also cause kidney irritation. If ingested, it can cause nausea, diarrhea, vomiting and abdominal cramps.

ORDER: TRICHOPTERA - Caddisflies
(*Tricho* = hair; *ptera* = wings)

These are small to medium-sized insects (<0.3-0.8 in.) mostly with dull colors. They have chewing mouthparts and the antennae are long, slender, and setaceous (Fig. 13-1: 14). They have wart-like tubercles on the thorax. The two pairs of wings have hairs and occasionally scales. The larvae are aquatic; found in streams and ponds. The larvae of some species are casebearers or net-bearers and feed on small plants (phytoplankton). The free-living caddisflies are predaceous.

Adult caddisflies are weak fliers. They lay eggs in water or on substrates near water and the larval development takes about a year.

Importance

The larvae of caddisflies are a good source of food for some fish species, such as catfish. The adults are weak fliers and stay close to their breeding habitat. They can become a problem, especially when present in large numbers at river or lake front communities. Their hairs and scales may cause allergic reactions in sensitive and asthmatic individuals.

ORDER: LEPIDOPTERA - Butterflies and Moths
(*Lepido* = scale; *ptera* = wings)

General Description

The members of this order vary in size (0.3-0.8 in.) and color. Their bodies, legs, and wings, in particular, are all covered with scales. The color of the scales ranges from dull white, gray, and brown to metallic blue, black, yellow, or orange red. Most butterflies and moths have siphoning-type mouthparts adapted for sucking liquid food. The antennae are of various types, ranging from club-shaped (clavate) to comb-shaped (pectinate or bipectinate). The compound eyes are large. There are two pairs of wings with the front pair longer and somewhat triangular as opposed to the relatively smaller and roundish hind pair. The lepidopterans undergo complete metamorphosis.

This is a large order with 11,000 species in North America.

Importance

Adult butterflies and moths are very colorful insects. However, their larvae are of considerable economic importance for they seriously damage a variety of plants and plant products. Some species feed on woolen materials and feathers. The larvae of approximately 10 families with over 50 species are known to possess urticating hairs. These hairs are hollow and may contain toxins. The toxins in some species are known to cause blindness. A brief description of these insects is provided in the following paragraphs.

Family: Arctiidae - Tiger Moths

General Description

The arctiids are small to medium-sized (0.3-0.8 in.) moths, which are conspicuously marked with bands or spots of bright colors. They hold their wings roof-like over the body when at rest. They are nocturnal in habit. Their larvae are brown to dark-brown in color, and their bodies are covered with dense hairs.

Importance

The larvae of most species possess urticating or nettling hairs, which cause itching and dermatitis-like conditions. The most common North American species is the hickory tussock moth, *Halisidota caryae* Harris.

Family: Lymantriidae - Tussock
Moths and Relatives

General Description

These are medium-sized (0.5-0.8 in.) moths, which are very similar to the noctuids except for a larger oriole in the hind wings and no ocelli. The larvae have long tufts or tussocks of hairs on their bodies, hence the name tussock moth (Fig. 13-1: 15).

This family includes some of the well-known pests of forest and shade trees, such as the gypsy moth, *Porthetria dispar* L., and the brown tail moth, *Nygmia phaeorrhoea* Donovan, in the northeastern U. S.; the Douglas fir tussock moth, *Hemerocampa pseudotsugata* McDunnough, in the west; and the white-marked tussock moth, *H. leucostigma* J. E. Smith, common throughout North America.

Importance

From the standpoint of public health, the nettling hairs of the larvae when ingested can cause some intestinal disturbances. A direct contact with these hairs may result in "caterpillar dermatitis" followed by pruritus, inflammation and wheals. May and June are considered to be the caution months when the larval development is at its peak.

Family: Lasiocampidae - Tent
Caterpillars and Lappet Moths

General Description

The lasiocampids are medium-sized (0.5-0.8 in.) stout-bodied moths with hairy bodies, legs, and eyes. These moths are brown or gray, some species have bluish gray wings with white markings (Lappet moths). The larvae are dark gray to almost black with yellow stripes or spots down the middle of the back, depending on the species. The forest tent caterpillar, *Malacosoma disstria* Hubner, is widely distributed, whereas, the eastern tent caterpillar, *M. americanum* Fabricius, is common in eastern North America.

Importance

The larvae attack a variety of plants, including forest, shade, and fruit trees. The larvae also possess stinging hairs that, upon contact, can result in skin irritation and dermatitis-like conditions.

Family: Saturniidae - Giant Silk Moth and Royal Moth

General Description

This group includes some of the largest moths in the world, measuring a wingspread of 10 inches. The antennae in these moths are bipectinate (feathery), being larger in males than in females. Their mouthparts are reduced, therefore, they cannot feed. The largest saturnid moth in the U.S. is the cecropia moth, *Platysamia cecropia* L., which has a wingspread of 5 to 6 inches. The reddish brown wings have white bands and a crescent shaped spot in the middle of each wing. The larvae of this species are green and 4 inches in length. They can be recognized by the two rows of yellow tubercles down the back and two pairs of farce red tubercles on the thoracic segments. Smaller moths, such as the io moth, *Automeris io* Fab., with a wingspread of 2 to 3 inches, is yellow with large eye spots on each wing. The spiny green caterpillars of this species have a narrow reddish stripe over a white edge extending along each side of the body. The buck moth, *Hemileuca maia* Drury, which is smaller than the io moth, is black with a narrow yellow stripe in the middle of each wing.

Importance

The caterpillars of the buck moth, io moth, and several other species have stinging hairs, which can cause itching and sharp stinging dermatitis. The range caterpillar, *Hemileuca oliviae* Cockerell, which is known to be very offensive to cattle, can cause blisters around their mouth area.

Family: Nymphalidae - Brush-footed Butterflies

General Description

The adults members of this family are medium to large-sized (0.5->0.8 in.) butterflies. They have the front legs reduced and without claws. Only the middle and hind legs are used in walking. The antennae are clavate (club-shaped) and the forewings have the radius vein 5-branched. Some of the colorful butterflies in this group include the viceroy, *Limenitis archippus* Kramer, the red admiral, *Vanessa atlanta* L., the painted lady, *Cynthia cardui* L., the hunter's butterfly, *Cynthia virginiensis* Drury, and the mourning cloak, *Nymphalis antiopa* L. (Fig. 13-1: 16).

Importance

From the standpoint of public health, *N. antiopa* deserves some attention. The adult butterflies are brownish black with yellowish outer wing margins. The larvae are gregarious and feed on poplar, willow, and elm trees. The larvae have stinging hairs, which upon contact with the skin can cause irritation and itching.

SUMMARY

The foregoing discussion clearly indicates several groups of insects causing public health problems ranging from a mere public nuisance to biting and stinging (through urticating hairs). There are those insects that: 1) cause or provoke human discomfort due to their presence in large numbers (biomass), such as springtails, bristletails, mayflies, psocids, and aphids; 2) cause discomfort and illness via ingestion of their body parts, or body secretions, such as earwigs, stink bugs, ground beetles, skin beetles, blister beetles, and caddisflies; 3) bite or pinch, such as earwigs, thrips, backswimmers, leafhoppers (jassids), tiger beetles, and some rove beetles; 4) cause dermatitis by stinging or urticating hairs of larvae, as found in various lepidopterous insects, such as various tussock moths, tent caterpillars, io moth, buck moth, range caterpillar, and mourning cloak; and 5) act as intermediate hosts for various tapeworms, such as some psocids and tenebrionids (flour beetles).

CONTROL

A majority of the insects referred to in this chapter are conceivably known pests of agricultural or silvicultural crops. Depending on their ecosystem and ecological niche, most of these insects are targeted in respective agricultural pest management strategies. By the same token, the low-level risk and cost-benefit ratio associated with these insects seldom call for designing independent control strategies in public health vector control programs. Nonetheless, the following list of recommendations can be helpful in dealing with the insects of minor public health importance, especially via public health information and education efforts.

1. Knowledge of the insect: Basic information on the biology and ecology of the insect(s) is important in developing some sort of preventive or control strategy.

2. Personal protection: This can be done in several ways:
   a) Avoidance: With a common-sense awareness about not touching or handling unfamiliar insects, one can avoid being bitten or stung by such insects.
   b) Protective clothing: Use of appropriate clothing may provide protection against injuries or inconvenience caused by biting or stinging insects.
   c) Protective screening: Insect-proof screens on doors and windows can minimize the entry of a variety of insects into homes.

3. Control methods:
   a) Swatting: Killing individual insects indoors with fly swatters.
   b) Vacuuming: Frequent vacuuming indoors helps in picking up insects and their body parts, which otherwise might pose as a source of allergies and nuisance.
   c) Protective treatment: A general perimeter application of approved (currently registered) pesticide around the house during the active insect season, at appropriate intervals, can be useful in controlling a variety of domestic and peridomestic insects.

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CHAPTER 14

SCORPIONS

Franklin Ennik[1] and Minoo B. Madon[2]

GENERAL CHARACTERISTICS

Scorpions are a very ancient order of Arthropoda often referred to as "living fossils." Relatives of these animals were among the first life forms to emerge from the sea onto land about 425 million years ago. Study of fossil specimens has shown that scorpions have survived relatively unchanged since the time of the dinosaurs. Today, scorpions are universally feared and unfairly maligned due to man's inveterate fear of these arachnids.

Among the popular scorpion myths that still persist, it is believed that: (1) a scorpion helplessly cornered will deliberately sting itself to death; (2) the toxicity of scorpion venom is related to the size or color of the scorpion; and (3) scorpions will not drink water.

BIOLOGY

Scorpions are easily recognized by their lobster- like pincers (pedipalps) and/or long tail terminating in a bulbous stinger. Like other arachnids, scorpions have four pairs of legs. The scorpion body consists of three parts: the cephalothorax, the preabdomen, and the post-abdomen. The head and thorax form the cephalothorax, which is covered by the carapace. On the carapace are none to six pairs of eyes, depending on the species; but scorpions have poor eyesight. Immediately posterior to the cephalothorax is the preabdomen. The tail or post-abdomen is composed of five cylindrical segments and a telson, which terminates in a stinger. Paired comb-like appendages, called pectines, are located on the ventral surface near the genital aperture. These structures are believed to have multiple functions, including tactile and auditory sensitivity, chemo reception, and perhaps others. Mature scorpions measure approximately 0.7 to 5.0 inches (213 cm) in length, depending on the species. Body coloration varies according to the species and ranges from pale yellow or cream to black.

Knowledge of scorpion biology is based upon observations obtained from a few species. Scorpions rarely are seen since they spend the daylight hours hidden in shelters and emerge at night to feed and move about. Increased activity has been observed during the new moon phase. Some ground-dwelling species live in excavated burrows, while others utilize existing ground depressions, crevices in rocks, or spaces under stones, bark, and other debris. Scorpions detect approaching predators and prey by sensory vibrations in the air and on the ground.

Scorpions are considered beneficial predators and feed on a wide variety of arthropods, which include soft-bodied insects, spiders, centipedes, and other scorpions. Some large species capture and eat lizards and small rodents. Scorpions, like a majority of other arachnids, ingest only the body fluids of their prey. Tiny bits of food torn off by the small claw-like chelicerae are pushed into the preoral cavity. Digestive juices then flow freely onto these bits of food, and the food is thus predigested outside then sucked into the stomach. Indigestible particles are discarded. The ingestion process is slow and can require several hours to complete.

LIFE CYCLE

Courtship and mating activity in scorpions is usually initiated by the male during the spring. Scorpion young are born alive (ovoviviparous) with the number of young per litter being affected by local conditions and species. The period of gestation is quite variable. At birth, the young scorpions are caught in a "birth basket" formed by the legs of the female. A membranous sack, which envelops the young at birth, is slit open, and the young egress and crawl upon the female's back. The newborn young do not feed and usually remain there until after the first molt. After their first molt, the young scorpions, which now resemble miniatures of the adult, will leave the mother's back to fend for themselves. Some

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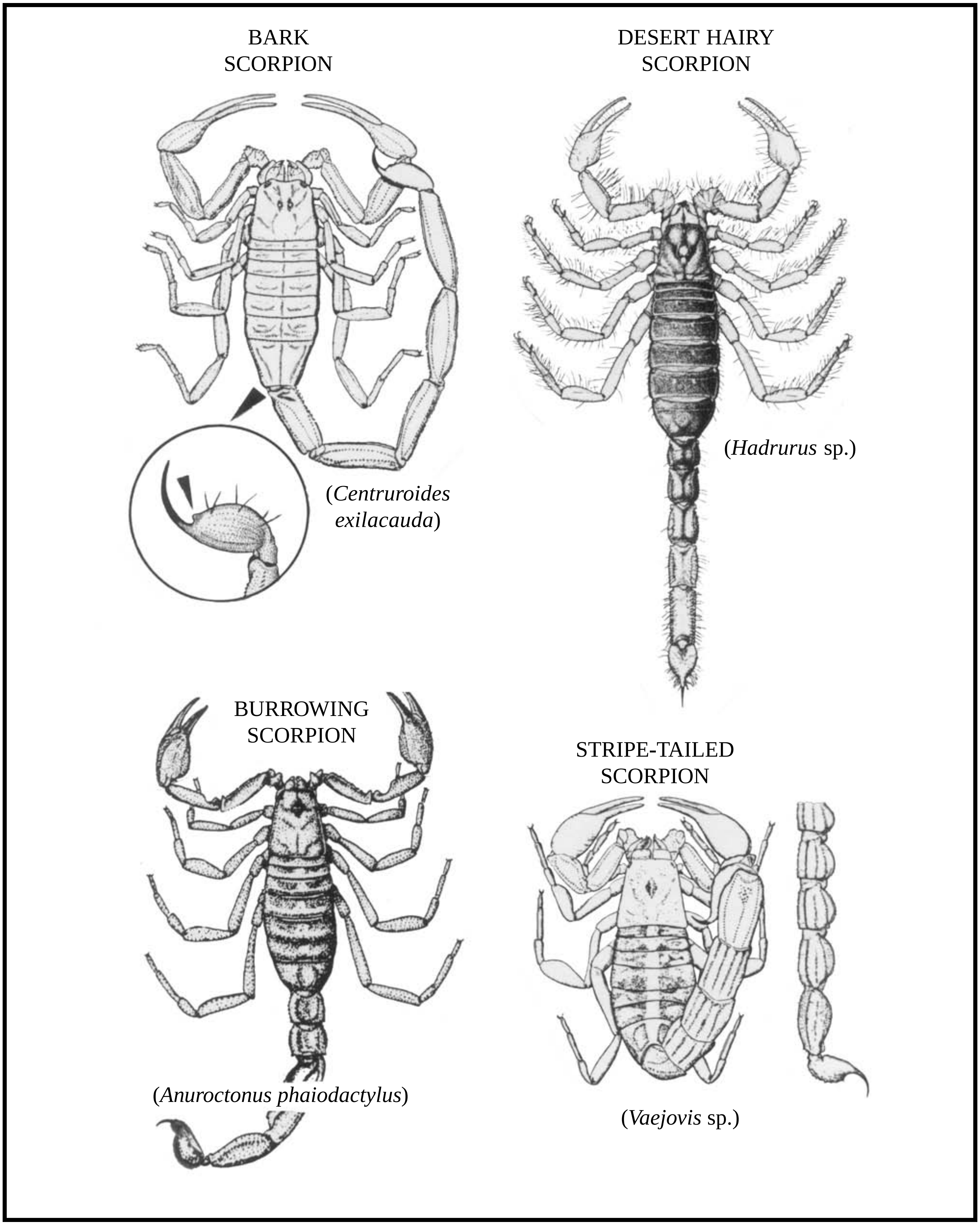

Figure 14-1. Scorpions (courtesy Pictorial Keys, CDC, 1966).

scorpions reach sexual maturity in about one year, while other species take much longer.

NOTABLE SPECIES

(Figure 14-1)

Most of the approximately 75 species recognized in the United States occur in the southwest. Unless otherwise stated, species and genera referred to by name occur in California. Species in the genera *Vaejovis*, *Paruroctonus*, *Serradigitus*, *Anuroctonus*, *Hadrurus*, and *Superstitionia* comprise most of the California fauna in the Central Valley and desert areas. Species of the genus *Uroctonus* are found in the moist regions of the Sierra Nevada and coastal California. The species of most medical concern to man, *Centruroides exilacauda* (formerly *C. sculuturatus*), occurs in western New Mexico, Arizona, in adjacent Mexico, and along the west bank of the Colorado River in California. This species has been reported with increasing frequency in recent years from residential areas of Los Angeles, Riverside, San Bernardino, and Orange Counties. These scorpions crawl up into recreational vehicles, boats, trailers, bedding, and other belongings, and are easily transported by vacationers returning to the urban environment from indigenous desert areas.

PUBLIC HEALTH SIGNIFICANCE

The painful stings administered by scorpions are intended to either subdue prey as well as provide self-defense. When a scorpion strikes defensively, the tail is lashed forward in a quick but well directed thrust, embedding the stinger momentarily into its victim. At the same time, venom is forced into the puncture wound. People are frequently stung while picking up objects because they startle or contact a hidden scorpion.

Scorpion venom may be rapidly fatal to invertebrate prey, but its effects on vertebrates, including man, are highly variable. The venom is comprised of a number of complex proteins that produce different toxic effects, including intense pain, itching, and tissue degradation. The severity of the reaction to scorpion venom depends upon the species of scorpion involved, the amount injected, and the size and susceptibility of the victim.

Scorpions are most active during the spring and summer months. Stings may occur any time of the day, but chiefly during the evening. In most cases the victim experiences localized pain and swelling. However, in a few cases the sting can produce a more severe allergic response from prior exposure to and sensitivity from the venom. Children are at particular risk because of their small size and their failure to recognize a potentially dangerous situation. Elderly or infirm individuals, especially those with underlying neurologic or cardiopulmonary diseases, are also at increased risk. In most cases, treatment of scorpion stings is entirely supportive since *antivenin* is not yet commercially available. Except for stings produced by certain *Centruroides* species and imported dangerous species, few stings are serious enough to warrant medical attention. However, a 12-hour observation period for delayed hypersensitivity effects is advised for all children under the age of 12 who have been stung by scorpions.

There are no first aid measures of established value in the treatment of scorpion stings. Placing a piece of ice over the wound site, for up to 10 to 15 minutes at a time, can reduce pain and cause some desirable local vasoconstriction. (Do not submerge the wound site in ice water or keep ice on constantly.) Steroids, anti-histamines, analgesics, sedatives, parasympathetic agents, and other drugs have been used with variable results. Antivenin for the treatment of *Centruroides* spp. stings is manufactured in Mexico, but is not licensed for use in the United States.

Precautionary Measures

Persons visiting or living in rural or undeveloped areas are more likely to encounter scorpions than those living in well-developed urban areas, and should exercise the following precautions:

1. Avoid walking barefoot outdoors, especially in the evenings.
2. Be careful when picking up objects under which scorpions may hide.
3. Move beds away from walls.
4. Inspect and shake clothing and shoes before wearing.
5. If one should feel something crawling on the body or neck, **brush** the object off. Swatting will trigger a sting, whereas, brushing will usually surprise the arthropod and may remove it before it responds.

SCORPION MANAGEMENT

Various methods can be used to control scorpions around dwellings. The suggestions listed below are directed at some aspect of their life cycle or habits that can be easily manipulated. Since human exposure to scorpion stings is greatest during the spring breeding season, preventive measures initiated before or during that time can be effective. Control possibilities include:

1. **Outside dwellings**. Accumulation of rocks, rubbish, lumber, and firewood should be moved away from living quarters since these provide excellent harborage. Storing lumber and firewood at least 18 inches above ground level will discourage harborage. Scorpions may congregate around moist areas in arid and subarid regions. Eliminating leaks from outdoor faucets, air conditioning units, and other water sources may be useful.

2. **Inside dwellings**. Scorpions occasionally wander into homes during the spring mating season and may be found anywhere on floors or walls, in the bathroom, or hidden under clothing and other items. Minimize access of scorpions into homes by weather stripping; and seal all cracks and crevices from the exterior, particularly those near ground level. Scorpions cannot climb a smooth vertical surface; and any modifications in construction, which will provide such surfaces, will reduce the possibility of invasion.

The preventive measures recommended above should suffice for most scorpion problems because scorpions do not usually enter homes or their immediate environs in great numbers. However, there may be circumstances where the application of an effective pesticide is desirable as a protective barrier outside the home and in selected areas inside the home (particularly when immediate control is needed).

Pesticide treatment regimens and application rates for scorpion control are based upon exposure results obtained from only a few species. It is assumed that a particular chemical useful against one species will also produce similar results against other species. Sprays should be applied to the foundation and entries into the house to control scorpions attempting to gain access. Outdoors, the entire perimeter, back and front yard, including firewood, lumber, and other stacked materials should be sprayed to control scorpions. Be careful to avoid damaging plants, which are sensitive to certain phytotoxic insecticidal formulations.

Applications of insecticides inside the home for these chance occurrences are usually not necessary. When the application of a chemical pesticide within a building is necessary, one should treat only places where scorpions are apt to enter or be hiding, such as baseboards, doorways, plumbing entrances, and building foundations. Tenting and fumigating the entire structure may be necessary if scorpions, especially *Centruroides exilacauda*, have become established within the building structure.

Large scorpion populations existing around dwellings may also be eliminated or greatly reduced during early spring months with the aid of ultraviolet light. The ultraviolet detection method of collecting takes advantage of two characteristics of scorpions: 1) scorpions are nocturnal, and 2) their integument converts ultraviolet radiation into reflected visible light, a greenish-blue fluorescence. The surveyor can easily and safely remove any detected scorpions with long forceps. By this means, it is possible to survey a suspect scorpion habitat quickly with minimal effort and habitat disturbance.

Scorpions are most active in complete darkness. Incidental light from street lamps, house lights, and moonlight masks the visibility of the fluorescent light. The user must use caution to prevent looking directly at the lamp or wear specially coated lenses since ultraviolet light can cause damage to the retina. When collecting at night, one must also use caution to prevent unfortunate encounters with rattlesnakes, which do not fluoresce.

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CHAPTER 15

SPIDERS

Franklin Ennik[1] and Minoo B. Madon[2]

INTRODUCTION

Most spiders found in or about the home present little or no public health significance. They are considered a nuisance because of their presence or because of the unsightly webs they make. Traditionally, the public perception of spiders has been a maligned one; the general viewpoint being that the bite of almost any spider is dangerous. Public fear may also be heightened by sensationalism created by the news media. The average person views all spiders as dangerous creatures. Spiders should be generally viewed as beneficial as they are, for the most part, predaceous on insects and other arthropods. Only a very few of the approximately 3,000 species that are known to occur in North America are considered harmful to man. These few species are capable of inflicting painful bites and the various reactions caused by the venom. Since most species are nocturnal and because of their small size, spider bite cases are usually accidental and rare occurrences. The reader is urged to refer to the articles and texts listed under Suggested Reading, and perhaps search for additional information on the Internet.

MORPHOLOGY

Spiders belong to the class Arachnida; Order Araneae. All arachnids are wingless and have four pairs of legs. Spiders are usually easily recognized. The body is divided into two main regions (cephalothorax and abdomen); joined by a narrow connection, the pedicel (Fig. 15-1). The dorsal portion of the cephalothorax (fusion of the head and thorax) is hardened and referred to as the carapace. The simple eyes (ocelli) are located at the front end of the carapace. Most spiders usually have eight eyes, but there are other species that have either six, four, or even two eyes.

The size and shape of the cephalothorax varies considerably with the species. The sternum is located on the ventral surface of the cephalothorax. The two chelicerae (jaws) are located at the front end of the sternum. The fangs are located at the terminal end of the two-segmented chelicerae. The poison glands are usually located in the basal segments of the chelicerae. The captured prey is usually paralyzed by the venom, or crushed by the strong chelicerae, and digestive fluids are introduced via the maxillary glands. The predigested fluids of the prey are then consumed. The pedipalpi are located on each side of the mouth. In females, these are simple appendages with a tarsal claw at the terminal end, whereas, in males, the distal end is modified into a special copulatory organ.

The unsegmented sac-like abdomen is connected to the cephalothorax by the pedicel. The abdomen differs considerably in size, shape, and coloration, depending upon the species encountered. The book lungs (located at the base of the abdomen) are represented by two slit-like openings (spiracles). Some species may have either a second pair of book lungs, a pair of tracheal spiracles, or perhaps a single spiracle located further towards the terminal end of the abdomen. The tracheae are considered to be more efficient respiratory organs than the book lungs. The copulatory organ of the mature female (epigynum) is usually situated between the first pair of book lungs. The web-spinning organs (spinnerets) are finger-like appendages located at the terminal lower end of the abdomen. Most spiders have eight spinnerets; some species have six.

BIONOMICS

Females lay a mass of eggs, which is enclosed in a silken sac. Not all egg sacs are spherical; some may appear as flattened disks. The newly hatched spiderlings remain in the egg sac for a short period. Eventually, when the temperature is warm enough, they emerge from the

[1]811 Seaview Drive, El Cerrito, CA 94530.
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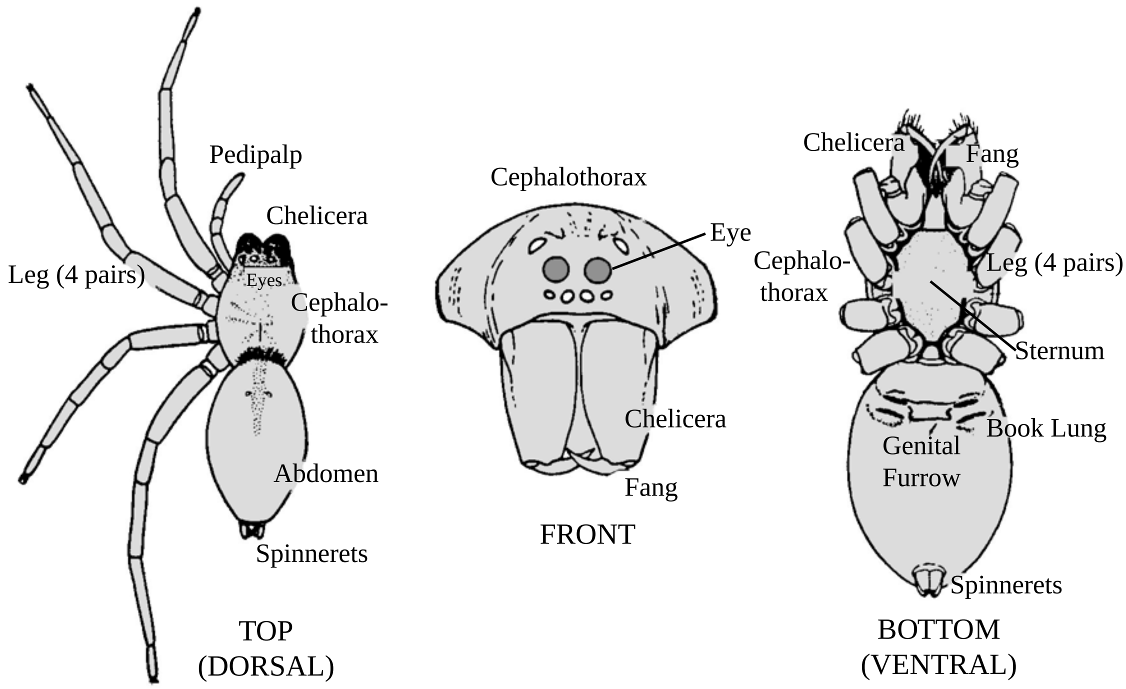

Figure 15-1. Spider anatomy.

sac and many species disperse by "ballooning." In this dispersal process the spiderlings move towards the terminal ends of either the grass, weeds, branches, or any other structure they happen to be upon, produce a long "dragline" of silken thread or threads, and depend upon the air currents to help them "balloon" away, sometimes distributing themselves great distances. The spiderlings undergo a gradual or incomplete metamorphosis. Depending upon the species, they undergo several molts (during the later stages, they become quite lethargic prior to molting) until they reach the adult stage.

Recently molted spiders appear much paler and softer, but gradually the integument hardens and darkens. The males usually do not live very long after reaching maturity and mating, whereas, the adult females may outlive the males by several weeks to months. Many species are known to live more than one year, and females of some species have been kept alive for about ten years. Female tarantulas may live up to 20 years or more.

Specific identification of spiders is often difficult and requires the services of a taxonomist. The general identification characteristics will be discussed at the generic level later on in this chapter. However, when you encounter individual specimens, we recommend that positive identification of the species should be confirmed by a taxonomist knowledgeable about spiders.

SPECIES OF PUBLIC HEALTH SIGNIFICANCE

Figures 15-2 and 15-3

Almost all spider bite cases occur when humans accidentally come in contact with them. They do not "attack" people as is popularly visualized. For instance, if they happen to be hiding in gloves, shoes, clothing, or bedding, and if they are about to be crushed, they may bite or attempt to do so in self defense. Occasionally, females "guarding" (or probably protecting) their egg sacs, or an aggressive species may perhaps bite at the slightest provocation.

One can expect that spider bites will result in at least discomfort, pain, or swelling at the bite site; however,

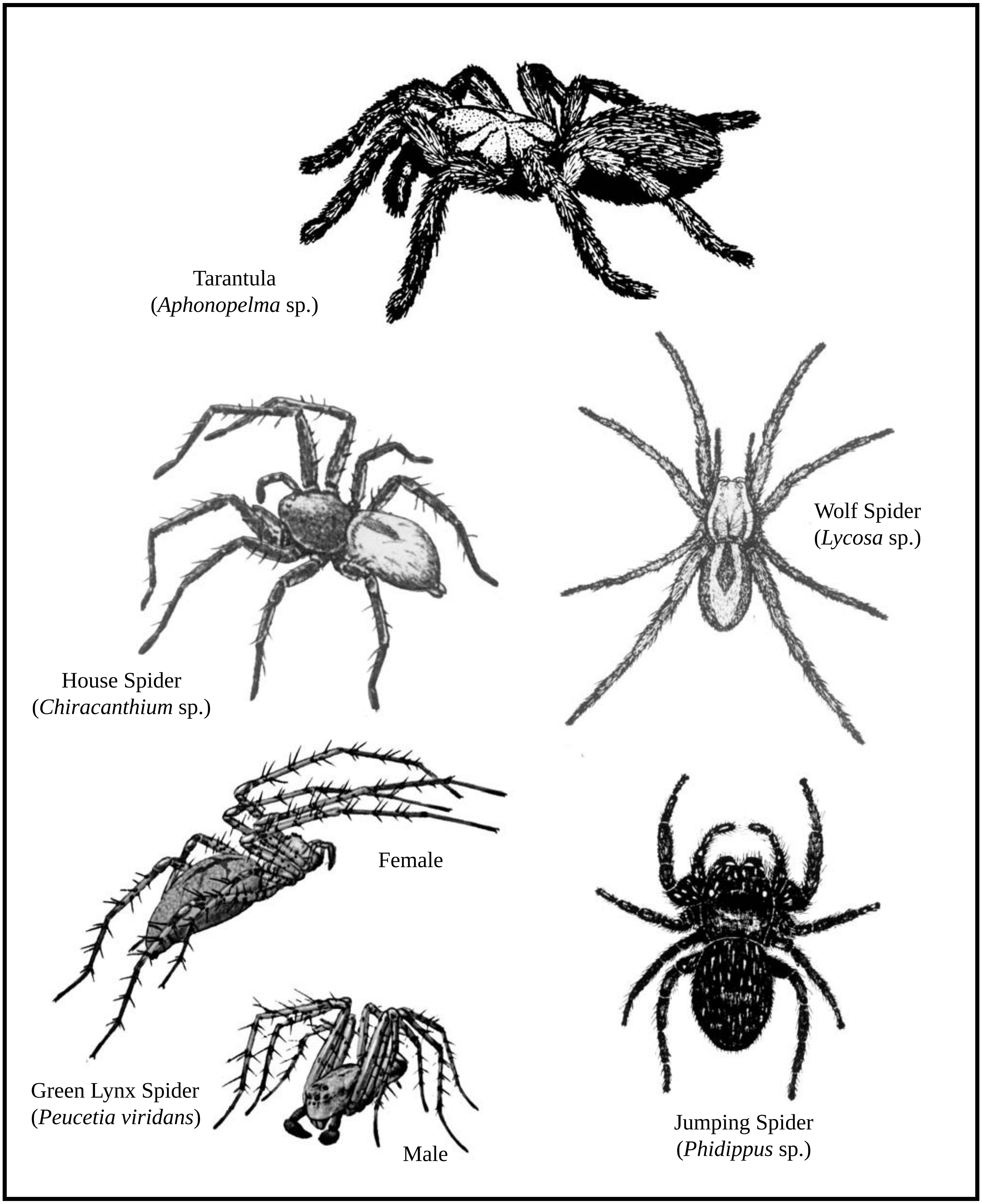

Figure 15-2. Spiders (courtesy Levi, Levi, and Zim, *Spiders and Their Kin*, Golden Nature Guide, 1968).

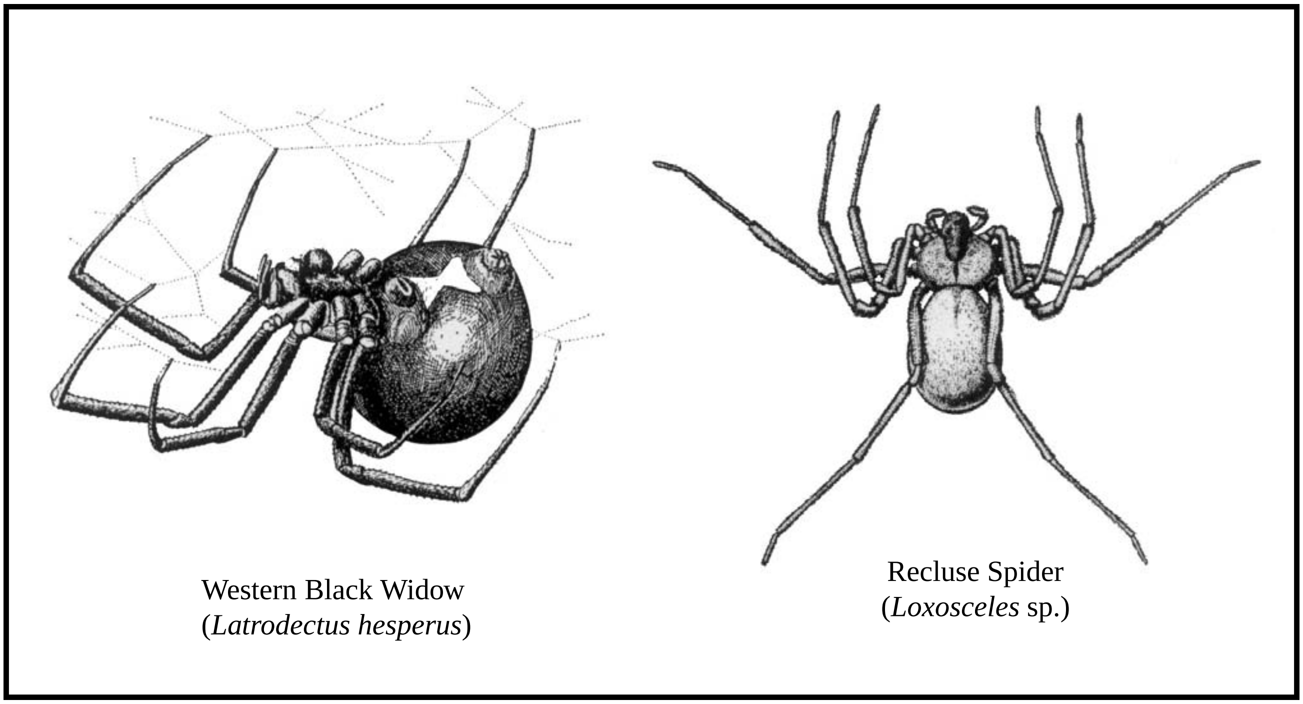

Figure 15-3. Highly venomous spiders (courtesy Pictorial Keys, CDC, 1966).

the actual consequences of the bites of most species of spiders are not known. The effects of the spider bite range from benign to severe, depending upon a complexity of factors, such as the site of bite, amount of venom injected, age, and physical health of the person. Some spiders are so small and weak that it is doubtful whether their fangs can even pierce the human skin. Others are of such a retiring nature that the possibility of human contact is minimal.

Bites by the members of several common families and genera will produce more than just transient discomfort and trauma. There are, however, several groups of spiders of known public health significance.

Black Widow Spiders

The venom of the black widow spider is a potent neurotoxin. The bite produces an intense stinging sensation with localized pain developing at the site of the bite in about 30 minutes, gradually progressing to the abdomen and legs. The pain may be quite severe for about 12 to 48 hours after onset. Other effects of the venom may include nausea, headache, and shortness of breath. Although deaths historically have occurred from lack of medical treatment, black widow bites are rarely fatal. The victim of a black widow bite should seek medical attention as soon as possible. Treatment usually is symptomatic and specific. Antivenin is available and only recommended in the most severe bite cases. Children under age 12 and older persons with cardiovascular problems are at risk for more serious side effects from bites. Clinical research has shown that muscle relaxants, such as calcium gluconate, are not helpful.

Violin Spiders, Brown Recluse Spiders

Several species of *Loxosceles* in the United States have been implicated in human bite cases. These include *Loxosceles reclusa, Loxosceles apachea, Loxosceles deserta,* and *Loxosceles arizonica.* Although *Loxosceles rufescens* and *Loxosceles laeta* have been implicated in human bite cases in the Mediterranean area and in South America, respectively, few if any bites from these species have been recorded in the United States. Bites by the violin spiders (*Loxosceles*) may cause a stinging sensation and pain, which does not usually develop for several hours following the bite. The venom of a *Loxosceles* spider is a highly specific cytotoxin that affects primarily skin tissues. A small blister usually develops at the bite site, which may enlarge and later become swollen and red. Eventually necrosis (localized death of tissue) begins, followed by the sloughing of the affected tissues, leaving a slow healing open wound. This phenomenon is referred to as necrotic arachnidism and Loxoscelism. A sunken scar usually forms; and, in severe cases, skin grafting is often required to repair the open wound. Human deaths are relatively rare compared to the number of people actually bitten by these spiders. Early medical intervention usually lessens the severity of bites. Necrotic spider bites should not be confused with ulcerating wounds caused by other complications or with flesh eating bacteria.

Other Common Spiders

There are a number of other common spiders in California, which have been known to bite humans. Various species belonging to the following families: Clubionidae, Gnaphosidae, Salticidae, Agelenidae, Lycosidae, Theridiidae, Araneidae, and Dipluridae are frequently identified in the more serious bite cases. Bites from these spiders have been reported to vary from transient pain and swelling to mild necrosis requiring medical attention and possibly hospitalization. Spiders of the genus *Tegenaria* (Agelenidae) have received a lot of media notoriety and are believed to be the cause of "spider bite" in the northwestern United States. Many species of this genus are common in Europe. Several species have been imported by commerce and now have become well established along the Pacific Coast of North America and Mexico. Species of this genus have adapted well to local environments and are now common in fields and residential backyards. Many alleged bite cases implicating this species are reported, but only a few of these are confirmed. Confirmed *Tegenaria* bites may produce mild necrosis and associated clinical effects similar to those associated with *Loxosceles* envenomation.

Tarantulas

It is difficult to induce native tarantulas to bite. Contrary to popular beliefs and the resultant imagined fears, tarantulas are not aggressive and rarely bite humans. Experimental evidence indicates that the venom of our several native species is not dangerous to humans but can be lethal to small mammals and insect prey. However, species of tarantulas imported from Central and South America may present a more serious threat. Their bite produces an injury that is a combination of both the mechanical puncture made by the large fangs and localized pain and swelling produced by the injection of the venom. If threatened, tarantulas will defend themselves by using their hind legs to rub off a small cloud of barbed hairs from their abdomen. These hairs can produce an irritating effect (urticaria) if an individual is sensitive and may cause a noticeable irritation of the mucus membranes and the eyes. Anyone handling tarantulas or keeping them as pets are at particular risk. Children are at particular risk of skin irritation and barbed hairs becoming lodged in the cornea of the eye or in the nose.

Other Arthropods

Soft ticks of the species *Ornithodoros coriaceus*, a parasite of deer, will occasionally bite humans causing an allergic reaction in sensitized people that clinically resembles *Loxosceles* spider bites. Other possibilities may include bites by conenose bugs, biting flies, or wasp stings. It is likely that the frequent reports of "necrotic arachnidism" implicating *Loxosceles* spiders, particularly in localities where they are not native or not likely to be found, can be traceable to other arthropods.

If bitten, an effort should be made to save the offending specimen for identification by a taxonomist and, if necessary, appropriate medical treatment by a physician. Speculation on the nature of an alleged spider bite without proper identification of the spider, or the offending species, may lead to misdiagnosis and improper medical treatment. As an additional precautionary measure, the bite area should be disinfected (mild soap and water). A cold compress or ice at the bite site may help prior to seeking medical attention.

Black Widow Spiders (Family Theridiidae)

The black widow spider of the western United States is recognized as *Latrodectus hesperus*. Adult females are black and shiny with a red "hourglass" marking on the underside of the pea-sized abdomen (Fig. 15-3). With legs fully extended, a typical mature female measures about 1.5 to 2 in. (3.8-5.1 cm) long with the body about 5/8 in. (1.5 cm) long. By comparison, the adult male black widow spider is seldom encountered and often mistaken for an immature. The males are usually black and much smaller with brightly colored chevron-like bands and spots on the abdomen. The female black widow usually hangs upside down in an irregular web formed of strong strands of silk or hidden in a webbed retreat. The strands run in many directions so the web appears as a concentration of irregularly arranged threads. *Latrodectus* webs exhibit considerable tensile strength and make a unique popping sound if broken or disturbed. Black widows adapt to a wide range of habitats. Webbed retreats are usually constructed at or near ground level. Typical web sites include spaces under rocks or log piles, under buildings and eaves, in meter boxes and culverts, under furniture, and in the corners of basements. In situations where insect prey is plentiful, the resident population of black widows may become quite large.

Life Cycle

Depending on the species, the female black widow constructs round to teardrop shaped egg sacs of white to cream colored silk into which she deposits ~ 70 eggs. These sacs are found suspended in the web from May to October and appear to be guarded by the female. Egg sacs are often parasitized by small wasps and flies. The eggs hatch in about two weeks and the spiderlings live inside the sacs for about two weeks before emerging. A few days after leaving the egg sac the immatures disperse by "ballooning." This method of aerial dispersal occurs during the early fall months. Male black widows go through only three to four molts to reach maturity, whereas, the females go through six to eight molts to reach maturity. Development of a female from egg to adult may require from 2.5 to 11 months. A female may live a year or more after maturity. When humans accidentally disturb the webbing, the female will generally attempt to escape, but may occasionally bite if the vibration/disturbance is mistaken for prey.

Brown Recluse Spiders, Brown Spiders, Violin Spiders (Family Siciariidae = Loxoscelidae)

Overview: Thirteen species of the genus *Loxosceles*, including two exotic species, are found in the United States. All species of *Loxosceles* spiders possess venom capable of causing skin necrosis and, therefore, are of public health significance. These spiders are easily transported via stored personal goods, interstate commerce, and from/to other parts of the world. For instance, the South American species, *L. laeta*, has become established in a number of cities along the east and west coasts of the United States. *Loxosceles rufescens*, another exotic species from the Mediterranean region, also has become established in many U.S. cities and throughout the world via the transport of commercial goods. The recessive behavior of *Loxosceles* spiders limits actual contacts with humans and the incidence of occasional bites to chance encounters.

Although the general appearance of *Loxosceles* spiders is nondescript, they can be identified by several specific characteristics. They generally lack integumental patterns or heavy spines like most other spiders. The cephalothorax and legs are usually tawny brown; the abdomen may be slightly darker or grayish in coloration. The immatures are colored similarly to the adults but are smaller in size. The total body length (cephalothorax and abdomen) of the adults ranges from approximately 3/8 in. (1 cm) to 0.5 in. (1.2 cm). Their legs are noticeably long, 1 in. (2.5 cm) to 1.5 in. (3.8 cm). All members of this genus have six eyes arranged in three pairs in a semicircle around the front of the cephalothorax. This characteristic eye arrangement separates the *Loxosceles* species from nearly all other spiders encountered in the United States.

The top of the cephalothorax of some species bears an obvious violin-shaped marking with the "scroll" of the violin pointing towards the abdomen. This violin-shaped marking is quite distinct on some species, whereas, on the southwestern desert species it is faintly visible.

Loxosceles spiders do not disperse by "ballooning"; they will live out their entire life in a confined area. Contrary to popular belief, they also do not actively migrate. Dispersion occurs only as a result of transportation by humans to new localities in personal and commercial goods.

Webs constructed by *Loxosceles* spiders are nondescript and have no apparent pattern or design. The extent of webbing may range from only a few strands of silk to heavy deposits in long-standing, undisturbed habitats. Indoors, webs may be constructed under or behind furniture, picture frames, and articles (old furniture, boxes, cardboard cartons, etc.) that have been stored undisturbed for long periods, especially in basements and/or attics. *Loxosceles* spiders do not rely only upon webbing for capturing prey, they also actively hunt prey away from their protective lair.

Mated females deposit one or more egg sacs during the early spring and summer months. Egg sacs contain 40 or more eggs and hatch in three to five weeks. The spiderlings reach maturity in 7 to 11 months. Immatures are commonly encountered during summer and fall, whereas, adults are usually found during late winter and early spring. In the molting process, *Loxosceles* spiders extend their legs and attach their claws to a substrate. The spider then extracts itself leaving behind the old skin with the legs outstretched in a "spread-eagled" manner, which is characteristic to the *Loxosceles* spiders. The immatures molt six to eight times and usually return repeatedly to the same spot to shed their skin. A cluster of two or more successive molted skins in this characteristic manner is a positive sign of a *Loxosceles* spider infestation (in the absence of live spiders).

Loxosceles deserta

Loxosceles deserta is indigenous to the deserts of southern California, western Arizona, southern Nevada, and adjacent Mexico. In California, *L. deserta* is encountered sporadically in the foothills of the southern San Joaquin Valley and in specific habitats across the Mojave and Sonoran deserts. This species is not known to exist in the Sierra Nevada Mountains or in the Coastal Range except where desert regions extend into these habitats. *Loxosceles deserta* populations have not yet been recorded north of an arbitrary line extending from Madera county to Fresno county. In arid regions of the southwestern deserts, *L. deserta* is often found under undisturbed accumulations of litter, rubbish, rock piles, abandoned manmade structures, and dwellings (especially abandoned homestead shacks). Wood rat (*Neotoma* spp.) nests and abandoned rodent burrows are also possible habitats. Although widespread, this species is seldom encountered because of its shy and retreating habits and its rarity in domestic dwellings.

***Loxosceles reclusa* (Brown recluse)**

This species is native to the Midwestern United States and is generally distributed in the Mississippi Basin area from Texas to western Georgia, north to southern Ohio, and westward to eastern Nebraska. *Loxosceles reclusa* has been transported by human activity to various other states and countries, including California, Arizona, North Carolina, Maine, New Mexico, Minnesota, New Jersey, Florida, Mexico, and Canada. In the southernmost states within its range, *L. reclusa* is associated with both the exterior and interior of dwellings; but further north it is increasingly found indoors inhabiting storage boxes, dark closets, and furniture. This species has not yet become established in California even though it has been found on a few occasions. These introductions have been clearly documented as cases of transportation from known indigenous areas.

Like other *Loxosceles* spiders, *L. reclusa* is not an aggressive species and will attempt to escape when disturbed. Most people are bitten when either donning infested clothing, gloves or shoes, or by rolling onto the spider in bed. Often, the victim may not realize being bitten. *Loxosceles reclusa* has received the most notoriety in the Midwestern U.S. because it is a common house spider and the large number of recorded bites.

***Loxosceles laeta* (South American violin spider)**

This exotic South American species was introduced into California probably via the transport of commercial goods. *Loxosceles laeta* appears to be well established in a number of cities in the San Gabriel Valley area (east of Los Angeles) and also in the downtown area of the city of Los Angeles. It has also occasionally been transported via commercial goods to the San Joaquin Valley. Among the *Loxosceles* spiders in North America, *L. laeta* is darker, the largest, and the most robust species. Due to its size, a larger amount of venom (which is reported to be the most toxic) may be injected into its victim. It is a major cause of necrotic arachnidism in South America.

Tarantulas (Family Theraphosidae)

About 30 species of Tarantulas are known to occur in the United States. Because of their large size, "ferocious" appearance, and notoriety these spiders are greatly feared by most humans. Several species occur in the more arid regions of California where they inhabit subterranean burrows and spaces under rocks. Tarantulas are large hairy spiders with stout bodies and legs, and brown to black in color. The long legs of the males in the southwestern U.S. extend 6 to 7 in. (15-18 cm). The body length measures about 1.25 in. (3.2 cm).

In early summer, mated females spin a cocoon of silk in which 500 to 1000 eggs are laid. The eggs hatch in about three weeks and the spiderlings remain in the cocoon another four to five weeks. After the young have dispersed by late September, the female molts and mates again before overwintering. Both sexes molt every year. During the breeding season, large numbers of tarantulas are observed crossing roads, highways, or open fields. These are usually mature males seeking females. Females can live up to 20 to 30 years, whereas, males may survive about 10 to 13 years and die shortly after maturing. During the fall, the female plugs the opening of her burrow and remains quiescent until the following spring, emerging to feed upon arthropod prey and deposit more eggs. Because of their retiring nature, the females are seldom seen.

SUPPRESSION AND MANAGEMENT

Prevention and Exclusion

Spiders usually reside where arthropod prey and adequate shelter are available. Although most spiders prefer outdoor environments, a few may inevitably wander into buildings and dwellings through the myriads of openings, cracks, and crevices that abound in most structures. The periodic appearance or presence of wandering spiders inside dwellings is seasonal, and usually related to their mating habits. Some may be transported inside on personal goods and commerce. Frequent house cleaning and control of other insect pests often will limit their numbers. A household or industrial vacuum cleaner can be used either indoors or outside the home and other buildings to physically remove live spiders and their webbing. Since many insects and other arthropods are attracted to lights, this encourages spiders to reside where food is plentiful. It is recommended that yellow "bug lights" be installed on porches and outside buildings, which will discourage congregation of nocturnal insects. Tightly fitting window screens and weather stripping will restrict entry of spiders as well as many of the prey they feed upon. Shrubbery and other vegetation also should be trimmed away from exterior walls, windows, and other likely points of entry. Sub-floor ventilators, fuse boxes, meter boxes, underneath porches and stairs, beneath furniture, and around and under outbuildings should be regularly inspected for infestations.

Simple precautionary measures to avoid spider bites include:

1. Prior to wearing, check clothing, gloves, and shoes that have been stored in garages or storerooms.
2. Boxes and containers with stored personal items should be carefully inspected before handling.
3. Firewood and other less frequently handled paraphernalia stored outdoors or indoors, should be carefully examined prior to handling.
4. Inside the home, one should habitually inspect the bedding for spiders taking refuge between the blankets and linen.
5. Installing yellow "bug lights" will prevent attraction of insects and other arthropods.
6. Weather stripping all doors and windows to prevent entry of insects and other arthropods.

Pesticides

If pesticides are used, it is imperative that only currently registered materials specifying the actual pest you are attempting to control is listed on the label. **Read all label directions and follow the recommended safety and precautionary measures.** In order to control spiders, special attention should be paid to spraying around door thresholds and sliding glass door frames. Applications of approved wettable powders and/or emulsions are recommended when broad coverage of yards, shrubs, and spot treatment are required.

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Notes

CHAPTER 16

CENTIPEDES AND RELATED ARTHROPODS

Richard P. Meyer[1] and Minoo B. Madon[2]

INTRODUCTION

Spiders and scorpions are well-known for the emotion and fear they evoke as a result of the severity of their bites, stings, and menacing form. There are other "provocative" arthropods that are much less feared, but as a consequence of their menacing form, they also are perceived as being dangerous. This perception is true for some species of centipedes and wind scorpions ("sun spiders") that are capable of delivering painful bites. There are still others that have chemical defenses (e.g., millipedes and sow bugs) to deter predators. With the exception of those being able to cause envenomation, severe bites, and chemical burns, the vast majority of arthropods are relatively harmless. This chapter will briefly review some of the more common arthropods related to spiders and scorpions with emphasis on groups that are of public health concern. Among the arthropods included herein are the centipedes (Class Chilopoda), millipedes (Class Diplopoda), wind scorpions (Order Solifugae), harvestmen (Order Opiliones), and sow and pill bugs (Order Isopoda). (Fig. 16-1).

BIONOMICS

The external form and anatomical organization of the arthropods presented in this chapter vary greatly from shapes that are either "worm like" in the centipedes and millipedes, "spider like" in the harvestmen and wind scorpions, or "armadillo-like" in both the sow and pill bugs. This diversity in form is adapted to suit the specific roles these arthropods provide in nature and within their immediate environment. Surprisingly, most species of arthropods are actually quite vulnerable to high temperature stress and desiccation. Accordingly, one behavioral characteristic shared in common is the trend to adapt to a nocturnal life style.

After sunset, when the air cools and humidity increases, they become active and move about to search for food, disperse, and reproduce. During the day, a majority remain hidden beneath rocks, logs, inside rodent burrows, and within the soil (digging species) where conditions are dark, cool, and moist.

With the exception of the scorpions that bear live young (ovoviviparous), the usual mode of arthropod reproduction involves male and female couplings followed by the female depositing her clutch of eggs in exclusion from environmental extremes, predators, and parasites. The female will then either abandon her "nest" or remain until the eggs hatch and the young disperse. The young begin feeding shortly after hatching and eventually will undergo a variable number of successive molts to reach sexual maturity.

CLASSIFICATION

The centipedes (Class: Chilopoda), millipedes (Class: Diplopoda) contains 10 orders in North America), harvestmen (Order: Opiliones), wind scorpions (Order: Solifugae), and sow and pill bugs (Class: Crustacea; Order: Isopoda) are distributed among a number of well-known classes and orders of arthropods. The centipedes and millipedes are distinguished by their unique body segmentation, mouthparts, and presence of antennae; the wind scorpions by their elongate form and imposing mandibles (chelicerae); harvestmen by their spider-like appearance and chelicerate mouthparts; and the sow and pill bugs by the segmented shell ("carapace") and leg arrangement.

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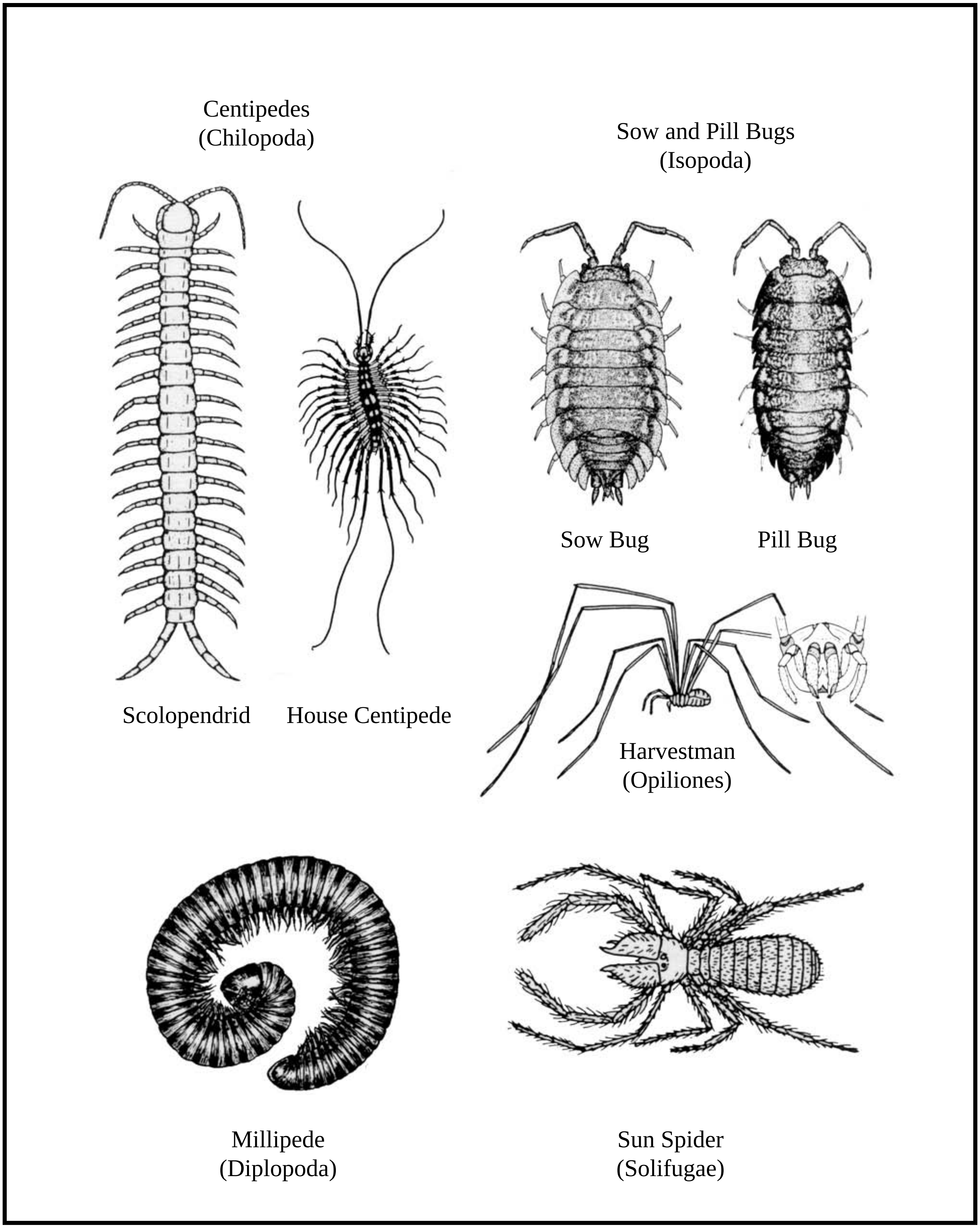

Figure 16-1. Centipedes and related arthropods (courtesy Pictorial Keys, CDC, 1966).

CENTIPEDES AND RELATED ARTHROPODS

Centipedes

The centipedes (cent = 100, ped = foot) are elongated and distinctly segmented arthropods that are particularly adapted to taking advantage of tight spaces under rocks, loose bark, and soil crevices. Their flattened profile facilitates entry into homes and garages where doors and windows do not seal completely. Even tiny gaps of less than 1/8 in. above the threshold will facilitate their entry. Mature individuals range in length from 2 to 6 in. (50-150 mm). Coloration of centipedes blends with their surroundings with most species being straw, red-brown, and greenish. Body segments of multicolored species are typically marked with contrasting dark-brown to black lines and blotches. The segmented nature of the body is typical, but there is considerable variability in the shape and form of the legs that can be short and robust in the typical scolopendrids to very long in the scuteregid or "house centipedes." Centipedes (e.g., giant centipede, *Scolopendra heros* in Arizona) are predators of other arthropods and small vertebrates . The first pair of legs ("toxognaths") in the scolopendrids are specialized for injecting venom. The bite delivered by one of the scolopendrids can be quite painful, but seldom dangerous in non-hypersensitive humans. Injection of the venom paralyzes the prey and immediately begins the digestive process by liquefying the internal organs and muscles.

Species belonging to the genus *Scolopendra* in California are considered to present the most danger to humans because of their potential venomous bite. These centipedes are encountered around the yard and garden throughout California with the exception of the alpine summits of the Sierra Nevada.

Scolopendra can be found in wood piles, beneath ornamental bark, baseboards of wooden fences, masonry stepping stones, and slabs. By comparison, house centipedes *(Scutigera* spp.*)* are not usually found in ground contact, but in the secluded corners (walls/ceilings) of garages and outbuildings. Centipedes overwinter as adults where there is adequate shelter within their immediate environment. Eggs are deposited in moist soil; and in some species, the surface of the egg is covered with a sticky film to which soil particles adhere to form a protective layer.

Solifugids

With exception of the scorpions, these fearsome arthropods invariably attract attention when they either venture inside the home or are encountered outdoors. The solifugids are often referred to as "wind scorpions," "sun" (sol= sun, fugae = flee) and "camel" spiders, with special notoriety as being able to move as "fast as the wind." Wind scorpions are hairy in appearance, straw colored, accented with reds and browns, and range in length from l to 2 in. (25-50 mm). Larger species are restricted to the desert with one exceptional species being found along the lower Colorado River. Solifugids are voracious feeders known for pursuing their prey and dismembering them with the scissor-like action of their chelicerae. The base of the hind two pairs of legs bear specialized "T" structures (racket organs) that sense ground vibrations.

Solifugids are more common in drier environments in California; but there are species that occur along the coast, at intermediate elevations in the mountains, and throughout the Central Valley. Among the more common species are those that belong to the family Eremobatidae in the genera *Eremobates*, *Hemerotricha*, and *Therobates*. The female will construct a subterranean egg chamber in which she lays her eggs. The eggs hatch in two to three weeks depending upon the species and prevailing environmental conditions.

Millipedes

Millipedes (milli = thousand, ped = foot) are tubular shaped arthropods that range in size from 1 to 4 in. (25-90 mm) and each body segment bears two pairs of walking legs. Coloration in this group varies considerably, with some species being bright yellow and orange to others that are wholly black to dark brown. In North America, millipedes are highly susceptible to moisture loss and thus restricted to moist environments. Species in arid areas of California, including the deserts, are found near the surface under logs and fallen yuccas during the winter and late spring. In moister environs, they occur year-round and often may be collected by turning over logs and old lumber in direct ground contact. Smaller species usually occur under loose bark during the winter and spring. Millipedes of interest include the large black species represented in a number of genera including *Hiltonius*, *Narceus*, and *Brachyilius.* The green house millipede *(Oxidus gracilis)* is a common species in urban areas where it is associated with landscape ground covers (mulch and chipped bark), wood piles, and potted plants.

Millipedes feed predominately on decaying vegetable matter, but some species are predacious while others feed on living plant material. Females deposit from 100 to 200 glossy white eggs in a nest-like cavity in moist humus or debris. Eggs hatch in two to three weeks. Newly hatched young have only three pairs of legs, and additional pairs are added with each successive molt.

Harvestmen

The harvestmen, or "daddy long-legs," are frequently confused with spiders and mistaken for long-legged or cobweb spiders *(Pholcus* spp.*)* that are found under the eaves of houses and out buildings. They are not spiders because the body consists of a single oval segmented mass and the fangs are absent. Instead, the mouthparts are chelicerate (claw-like). California species are usually dark with some irregularly pattered with blotches of gray, white, and tan. Although the body length of mature individuals is only 0.25 in. (8-10 mm), the legs are exceptionally long, 1.5 to 4.0 in. (37-100 mm), and patterned with either contrasting pale rings or blotches.

Harvestmen are distributed statewide, occur in virtually every habitat where favorable conditions exist, but are most abundant in areas that receive soaking winter rains. Seasonally, they are active during the moist cool months of the year and avoid the heat and low humidity of summer. The more common species belong to several genera, including the well-known *Protolophus* and *Leuronychus.*

"Daddy long-legs" are encountered in low growing vegetation, beneath stones, crevices of wood piles, and under the eaves of buildings where they are sometimes found aggregated in masses of 10 to 20 individuals. These arachnids feed on the carcasses of dead insects and other arthropods and do not bite, even if mishandled. Females lay eggs via a long flexible ovipositor that is inserted into most soil. Upon hatching, the young dig free of the egg chamber and seek protective shelter above ground.

Sow and Pill Bugs

These two "armadillo-like" crustaceans of the order Isopoda (Iso = equal, poda = foot) are familiar inhabitants of every backyard. The common sow bug *(Porcellio laevis)*, 0.5 in. (15 mm), and common pill bug *(Armadillidium vulgare)*, 0.3 in. (10 mm), are easily separated by overall size, the presence of two caudal (tail-like) appendages in the sow bug, and the capability of the pill bug to roll itself into a ball (= pill). Both are colored similarly in various shades of gray, but pill bugs are normally darker with contrasting stripes on the shield plates. Like the millipedes, sow and pill bugs emit an acrid fluid that is "distasteful" to most predators. Many, however, still fall victim to spiders.

Where found, sow and pill bugs are usually associated with moist, humid conditions beneath rocks, debris, wood piles, lumber, leaf litter, and commonly flower pots. They are a pest when their populations abound and mass feeding results in damage to ornamental plants, fruits, and vegetables.

Females deposit their eggs in moist soil/humus with hatching occurring in two to three weeks. The young stay sedentary for a short period and quickly disperse when overcrowded. It is not uncommon to find either small clusters or aggregated masses of sow and pill bugs containing mixed juvenile stages along with adult males and females.

MEDICAL IMPORTANCE

Arthropods inevitably gain the attention of a public that fears these creatures for harboring dangerous venoms and delivering painful bites. Although totally unfounded, this perception is likely attributed to some species of centipedes (e.g., *Scolopendra)* that can render a painful bite, but for the most part, the mere "form" elicits phobias related to natural fear reactions. Harvestmen are completely harmless, but feared due to their likeness to certain spiders. Similar is the case with house centipedes, millipedes, and pill and sow bugs. Wind scorpions, by the presence of their grotesque chilicerace ("jaws") are understandably considered potentially dangerous even though our native species are not venomous in comparison to some species found elsewhere in the world. Lacking venom, their strong chelicerae still are capable of delivering a painful bite.

Envenomation

The bite of scolopendrid centipedes includes the injection of a mild venom that produces a bee sting-like reaction. Centipedes do not possess fangs as in the spiders, but a more elaborate system with the specialization of the first pair of legs as venom injecting "toxognaths." After the initial injection and painful reaction, subsequent reactions may include local swelling, soreness, and intense itching several days after the bite.

Most bites can be treated with conventional sting treatments, but in individuals that are sensitive to the venom, hypersensitive reactions can produce a heightened response, including potentially lethal anaphylaxis. Therefore, if accidentally bitten by a scolopendrid, it is best to seek immediate medical attention.

Chemical Defenses

A number of millipedes, and to a lesser extent sow and pill bugs, produce chemical exudates comprised of caustic chemicals (e.g., quinones and hydrogen cyanide) that are intended to deter predators. When the animal is either disturbed or mishandled, blackened droplets containing the caustic chemicals are quickly exuded through specialized pores that extend the length of the body parallel to the legs. Applied to human skin, these chemicals normally produce intense burning and subsequent blistering if the affected area is not washed immediately. Defensive chemicals are extremely distasteful and will often produce a regurgitation reaction. Similar substances are produced by "stink" beetles (*Eleodes* spp.) belonging to the family Tenebrionidae (refer to Chapter 13).

MANAGEMENT AND CONTROL

Integrated Pest Management (IPM) Strategies

Managing arthropods presents unique alternatives because there are no formally set procedures for controlling these pests in either urban or rural settings. Problems with chemical control arise when deciding where treatments should be applied because many target species are highly mobile, behave in a manner that limits contact with treated surfaces, and possess large bodies requiring significant contact with a labeled chemical that can "effectively" kill them. Chemical treatments and poison baits are perhaps most effective with sow and pill bugs. Both are relatively small and move about with significant contact with the ground or other surfaces.

Another factor that works against effective chemical control is the reality that most of the arthropods presented herein are often encountered only as single individuals or as small numbers of individuals aggregated in isolated groups. Further complications arise where these arthropods are driven from weedy lots and native habitat by weather, vegetation removal, and loss of food supply.

The best method to manage these arthropods is via source reduction and exclusion. This requires systematic removal of sites where these arthropods can hide or take refuge. For centipedes, millipedes, sun spiders, and to some extent harvestmen, the best solution for exclusion is to periodically remove all debris from flower beds, elevate wood piles, and make sure that all cracks and gaps in exterior wood work, fences, and masonry are sealed. Outdoor storage sheds should be inspected at least twice yearly for evidence of infestation and treated if necessary with an approved pesticide.

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Notes

CHAPTER 17

MITES

James P. Webb, Jr.[1] and Stephen G. Bennett[1]

INTRODUCTION

Mites are distant cousins of insects and are distinct from them in having a fused cephalothorax joined broadly with an unsegmented abdomen. This characteristic, as well as having four pairs of jointed legs as adults, places the mites in the class Arachnida. Insects have three well-defined body regions and three pairs of legs. Ticks and mites are closely related and grouped together in the subclass Acari but mites are generally smaller and lack an armed (toothed) hypostome (mouthpart) adapted for piercing and attachment.

Most mite species are of no public health importance. A large number of them are plant-feeders, proportionately fewer are predators, and fewer still are parasites of animals. Within the last group are species that are important as pests or vectors of disease agents to humans and/or their domestic animals. In California no mite species are known to transmit any disease-causing microbes.

Mites are generally small in size (0.1-2.0 mm) and many require microscopic examination to be seen for identification. To correctly identify mite specimens, they should be mounted on microscope slides and observed under high magnification (400-1000X) using a compound microscope. Specimens sent to a medical acarologist for identification may be shipped in 80 percent ethanol or mounted on a slide using appropriate preparation techniques and mounting medium.

The following discussion of mites of medical importance from California adheres to the taxonomic, systematic, and bionomic recommendations of Krantz (1978) and Lane and Crosskey (1993). Other relevant references are also included at the end of this presentation.

General Life Cycle (Figure 17-1)

Mites may pass through six (usually) stages (instars) after hatching from the egg. These include the prelarva, larva, protonymph, deutonymph, tritonymph, and adult. The typical mite larva is six-legged, soft-bodied, and without genitalia. The protonymph (first nymph) usually is an active free-living eight-legged stage, which may or may not feed. The deutonymph (second nymph) attains the general characteristics of the adult including the possession of eight legs but it is different in size, sclerotization pattern, and lack of sexual structures. In some species the deutonymph is heteromorphic, non-feeding, and phoretic (hitchhiker); this stage is referred to as a hypopus. The tritonymph (third nymph) is found only in a few mite groups and is usually an active stage. This nymphal instar is followed by the adult stage that consists of male and female sexual forms.

Mites of medical importance are systematically placed in three suborders based upon the presence or absence and body placement of the respiratory organs (stigmata) (Fig. 17-2).

Suppression

Under some conditions pesticides (acaricides) may be used to control certain mite populations. The pesticides must, however, be used in a manner consistent with the label, which requires initially that the target animal(s) must be identified. If the tried pesticide is ineffective against this species after being applied according to label specifications then another one with a different active ingredient (a.i.) may be employed. Resistance to commonly used acaricidal chemicals develops with relative speed and is often the reason for pesticide failure.

Treatment

Most of the mites discussed herein cause skin irritation (dermatitis) which can be treated with a topi-

[1]Orange County Vector Control District, 13001 Garden Grove Blvd., Garden Grove, CA 92843.

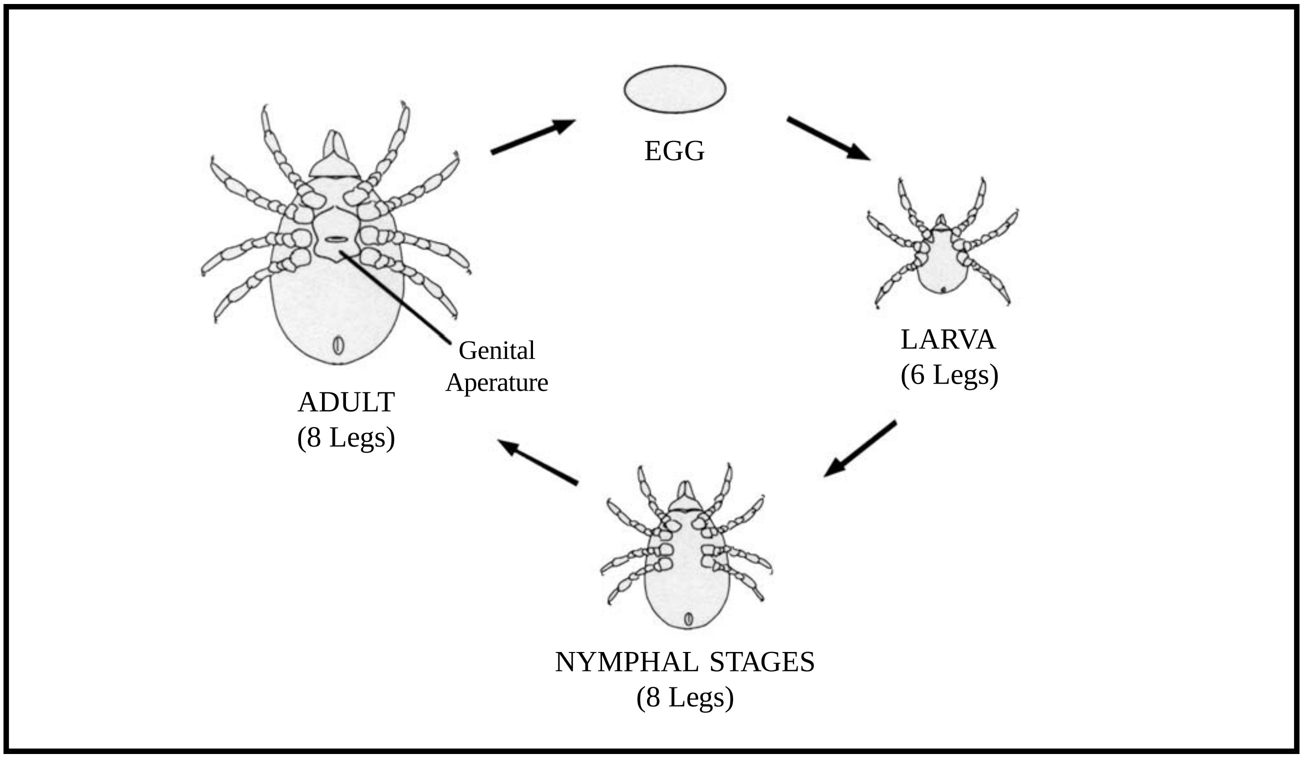

Figure 17-1. Generalized mite life cycle.

ally applied palliative. More severe and persistent skin conditions should be examined by a physician. Scabies (itch mite) infections should be treated by a physician who would likely prescribe a topical acaricide. People who have house dust mite sensitivities may opt to undergo desensitization therapy by an allergist.

Order Acariformes

Suborder Actinedida (= Prostigmata)

Family Demodicidae

(Follicle Mites)

Classification - Distribution

Two species in this family are known to be of medical importance, *Demodex folliculorum* (Fig. 17-3), and *Demodex brevis*, and have a worldwide distribution.

General Characteristics

Demodex folliculorum and *Demodex brevis* are minute (0.1 - 0.4 mm) mites with annulated, worm-like bodies. In both species, larvae and protonymphs each has three pairs of non-jointed stub-like legs, nymphs have four similar pairs, and adults have four jointed more prominent leg pairs. The adult male of both species has a dorsal forward-pointing penis situated above the walking legs and the female of both species has a slit-like ventral vulva.

Life Cycle

Eggs are laid one at a time and develop to complete three-legged larval forms before hatching. The larval exoskeleton expands and hardens immediately after hatching followed by larval feeding that is accomplished by puncturing cells and sucking out the contents. Larvae metamorphose into protonymphs, followed by the nymphal stage, and then the adult male and female stages. Females average a total of approximately 20 eggs, which develop sequentially. Unfertilized eggs develop into males, which are haploid (n = 2) and fertilized eggs develop into diploid (n = 4) females. The estimated time span for the entire life cycle of *Demodex folliculorum* is 14-15 days.

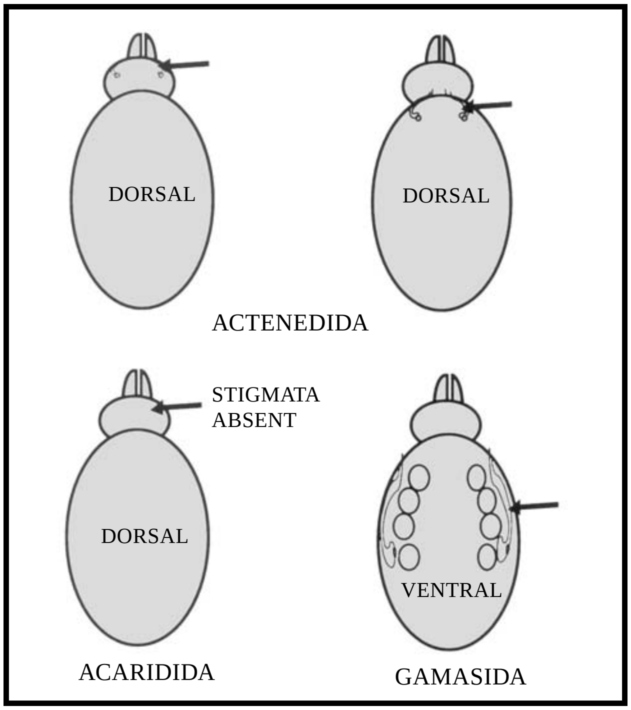

Figure 17-2. Respiratory organs (stigmata) that characterize three suborders of mites; Actenedida (= Prostigmata); Acaridida (= Astigmata); Gamisida (= Mesostigmata).

Bionomics

Both *Demodex brevis* and *Demodex folliculorum* have been recovered from the surface of the skin. *Demodex brevis* immatures, eggs, and most adults are restricted to the sebaceous glands; *D. folliculorum* immatures, eggs, and adults reside more commonly in the hair follicles. The topologic distribution of these two *Demodex* species on humans includes the scalp, forehead, eyelids, ear canal, nasolabial folds, nose, axillae, and perianal area. It seems that all races of *Homo sapiens* possess one or both of these demodicid species. Various estimates of the incidence of human infesting *Demodex* species ranges from 25-100 percent. *Demodex* species naturally found in the skin of other animals do not infect humans.

Public Health Significance

The significance of demodectic mites as pathogens to man or vectors of human pathogens is debatable depending upon interpretation of the results of various research projects. Some investigators attribute certain skin diseases to *Demodex* species whereas others

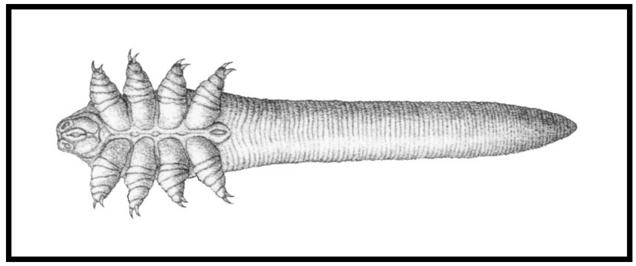

Figure 17-3. Follicle mite, *Demodex folliculorum*; after Hogue, 1993.

contend there are no proven detrimental effects due to the presence of these mites.

Disease causation is hard to assess but with extreme mite infestations dry, reddening and scaly skin on the face and eyelids may occur. Close contact between individuals accounts for the transmission of mites from an infected host to a new host.

Treatment

Daily washing of the affected area with a mild non-medicated soap and an appropriate dermatologist-recommended topical medication.

Suborder Actinedida

Family Cheyletiellidae

Classification - Distribution

Five species are presently included in the genus *Cheyletiella*; three species that affect people include *Cheyletiella yasguri* (on dogs) (Fig. 17-4), *Cheyletiella blakei* (on cats), and *Cheyletiella parasitovorax* (on rabbits) and are worldwide in distribution.

General Characteristics

Cheyletiella spp. are small (0.5-0.7 mm) mites with elongated and oval bodies. The dorsum of the body has one to three dorsal shields and no eyes. The fangs (chelicerae) are short and modified for piercing and the palpal claw is usually curved ventrally, an adaptation for holding fast to the host. The male genital opening is situated on the dorsum (backside).

Life Cycle

The species of *Cheyletiella* have six distinct life stages: egg, prelarva, larva, two nymphal stages, and

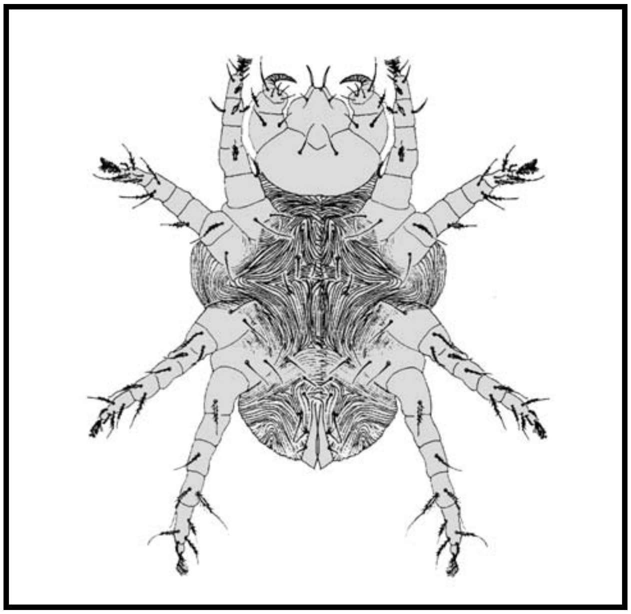

Figure 17-4. *Cheyletiella yasguri;* found on dogs; after Bronswijk and Kreek, 1976.

adult (separate sexes). The whole life cycle is completed on the host. Eggs are attached to the host's hair shafts 2-3 mm above the base by means of finely woven threads. The threads are shaped into a cocoon-like structure that houses the egg inside of which the pre-larva and the larva develop. Larval through the nymphal stages (2) mature during their development by the process of feeding and molting. Before each molt the mite becomes swollen, sluggish, and quiescent. The new stage can be seen inside the old skin. The duration of each stage is not known with certainty.

Bionomics

Cheyletiella species live on the surface of the skin of their hosts where they move around the skin debris at the base of hairs. The preferred attachment site for feeding is on the dorsal skin of the host. The stylet-like chelicerae are used for piercing the skin during feeding followed by the mite becoming engorged with a colorless fluid.

There is a high level of host specificity exhibited by *Cheyletiella yasguri*, *Cheyletiella parasitovorax*, and *Cheyletiella blakei*, i.e., each of these species is restricted to their preferred host, dogs, rabbits, and cats respectively. Attempts to transfer cheyletiellids from one host species to another have been unsuccessful. The lack of stimulated adverse cutaneous reactions by each of the *Cheyletiella* species in their preferred host species suggests a long-term mutually adaptable association.

Public Health Significance

Pet owners are at a small but measurable risk of being attacked by mites of this group that are infesting their pet. Topical dermatitis (skin inflammation) with patient complaints about itching on the arms, breast, and/or abdomen may result from human contact with *Cheyletiella* species. Water-filled vesicles and scratches may occur at the sites of irritation as well. These symptoms may sometimes be scattered over the whole body surface. Diagnosis of human contact with pet-associated cheyletids is accomplished by demonstrating a mite infestation of the pet. Brushing the animal's fur with a stiff brush over a piece of paper will indicate the presence of mites, which are visible to the naked eye. Recovery of the mites, preparation on microscope slides, and examination under a compound microscope will confirm the infestation.

Suppression

Application to the pet's fur with an acaricide recommended by a veterinarian.

Treatment

Appropriate medically suggested lotions or ointments may give relief from the itching. Topical corticosteriods to reduce inflammation and oral antihistamines to relieve itching are recommended.

Suborder Actinedida

Family Trombiculidae

(Chigger Mites)

Classification - Distribution

Referred to as chigger mites, more than 3,000 described species are distributed worldwide. A small number of chigger species (12-14) represented by nine genera has been shown to bite people resulting in mild to adverse skin reactions. In Southeast Asia and the western Pacific, one of these genera *(Leptotrombidium)* also has representatives that transmit the causative agent of Scrub Typhus (*Orientia tsutsugamushi*, a rickettsia).

Two species of chiggers are known in California that bite man and cause extreme skin discomfort. Both species are in the genus *Eutrombicula: Eutrombicula belkini* (Fig. 17-5) and *Eutrombicula batatas*. *Eutrombicula belkini* is known from northern, central, and southern California, southern Nevada, Utah, western Colorado, New Mexico, southeastern Arizona, southern Texas, and Mexico (including Baja California). *Eutrombicula batatas* is reported from Florida, Georgia, Alabama, central California, Arizona, Kansas, Mexico, and Central and South America.

General Characteristics

The taxonomy of the trombiculid mites is based primarily on the larvae. *Eutrombicula* species larvae are small (0.25 mm), red, and six-legged. Mouthparts (pedipalps and chelicerae) are modified for grasping and piercing the skin, respectively.

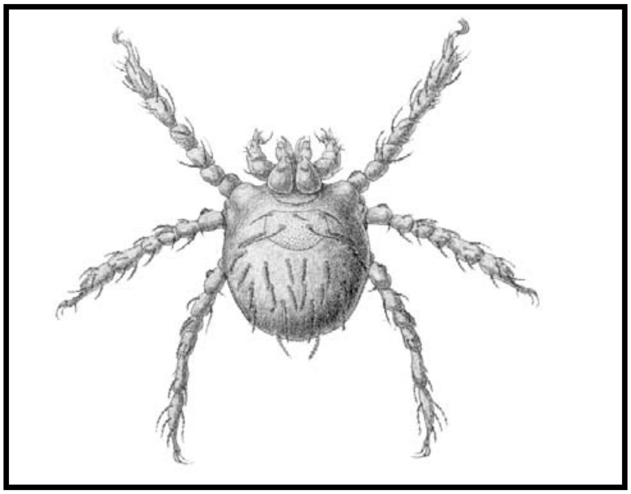

Figure 17-5. Larval trombiculid mite (chigger), *Eutrombicula belkini;* after Hogue, 1993.

The body bears a dorsal plate (scutum) at the level of the anterior two pair of legs. There are two pairs of eyes that flank the scutum, which bears five marginal setae, and a pair of branched sensillae. The body also has several rows of dorsal setae, several rows of ventral setae, and a ventral anus.

Nymphs and adults (separate sexes) are about 1 mm in length, oval, and figure-8-shaped. Their bodies are densely covered with setae giving a velvety appearance. Both post-larval stages have eight legs. The palpal tarsus and the stout blade-like chelicerae are modified for grasping. The genital opening is located between coxae IV. The genital openings of both sexes are flanked with numerous setae on the longitudinal genital valves; males have a blade-like penis.

Life Cycle

Adults live in the ground litter or soil where they are predators on small arthropods and their eggs. Males produce and deposit on the ground a stalked structure called a spermatophore in which sperm cells are stored. Females incorporate the sperm-containing portion of the spermatophore into their genital opening. Shortly thereafter fertilized eggs are deposited onto the soil. The six-legged larvae hatch approximately one week later and begin to search for a host. *Eutrombicula batatas* prefer small mammals as hosts; larval *Eutrombicula belkini* are usually found on lizard hosts although small mammals and birds are also parasitized. After feeding, the larva drops off the host, enters the soil, and develops into a quiescent phase. This stage (nymphochrysalis) lasts for several days from which emerges an active, predaceous, eight-legged nymph. After a feeding period, the nymph enters into a second quiescent phase (imagochrysalis) from which emerges the active, predatory, sexually mature adult. Adults begin reproductive activities about two weeks post-emergence. Depending on the species and ambient conditions the life cycle can be completed in 50 to 75 days.

Bionomics

Chiggers actively quest and search for a host within a day after hatching. Larval *Eutrombicula belkini* are associated with coastal sage and chaparral plant communities. Grasslands, particularly ones composed of wild oats *(Avena fatua)*, also support active *E. belkini* populations. Heaviest concentrations of this species are sometimes found at the base of clumps of sagebrush in an ecotone of sagebrush and grass. *Eutrombicula batatas* is affiliated with more moist conditions and also with herbaceous vegetation and grasses. In California, collections of *E. batatas* are known from wet grasses adjacent to ponds in parks and from moist lawns near homes.

Public Health Significance

A few species of chiggers (including *E. belkini* and *E. batatas*) are known to bite humans in North America and cause a severe pruritic (itching) dermatitis (inflammation of the skin). No disease-causing microbes (bacteria, viruses, etc.) are known to be transmitted by these species.

Trombiculosis is the name given to the itchy skin inflammation caused by the bite of a larval trombiculid mite. Most bites occur on the body where clothing is constricted and a chigger moving upward on a human host stops to feed. This results in a bite pattern around the waist (belt-line) and ankles (sock-line) attributed to chigger mites. The bite is not felt but within several hours intense itching begins. Shortly thereafter an itchy papule capped with a water-filled blister develops. Scratching the irritated site often results in secondary infections. The lesions may continue to itch and weep for several days.

Suppression

Pesticide treatment to eliminate or control chigger mites is usually not feasible or practical. An exception to this generality may be for infestations by *Eutrombicula batatas* of park and home lawns where application of a label-approved acaricide may be effective. In lieu of treating chigger bites, a number of repellents (e.g. DEET) may help in preventing the chiggers from climbing onto a person.

Treatment

Treatment of chigger bites may involve over-the-counter anti-itch and, if necessary, anti-bacterial ointments. Consult your physician if the lesions persist and do not heal within a week.

Suborder Actinedida

Family Pyemotidae

(Straw Itch Mites)

Classification - Distribution

The major genus in this family, *Pyemotes* (Fig. 17-6), is divided into two species groups: one group includes species that are associates of bark beetles *(Scolytus* spp.) and another, including *Pyemotes tritici* (= *Pyemotes ventricosus*, in part), that are parasitic on the larvae of grain-infesting moths and beetles. *Pyemotes tritici* has medical importance to humans and is distributed worldwide.

General Characteristics

The pyemotids are extremely small (0.2 mm), soft-bodied mites with functional stylettiform (piercing-sucking) chelicerae (mouthparts) in both sexes. The last segment of the first pair of legs (and the last pair in males) terminates in one claw; the other legs end in two-pronged claws. The opisthosoma (abdomen) of the female becomes enormously distended with developing young.

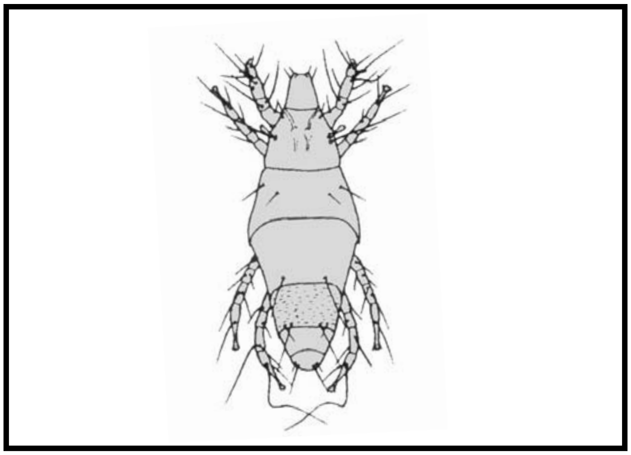

Figure 17-6. Female straw itch mite, *Pyemotes tritici;* after Lane and Crosskey, 1993.

Life Cycle

Fertilized adult female pyemotid mites feed on the hemolymph of parasitized larval insects. As it feeds, her opisthosoma swells and in a few days movement is impeded by the large size. After another week the fertilized eggs begin to develop inside her body through the intermediate stages until maturation into adult males and females. Between 200 and 300 offspring are produced by each female. Usually the first born is a male which remains on the female near her genital opening. The males receive nutrition from the females by feeding on substances produced in the genital area. Males live from 4 to 14 days while on the mother, fewer days if removed from her. While on the female the newly born males await the birth of the females and copulate with them as soon as they are born. Inseminated females seek out new larval insect hosts where they begin the life cycle anew. Some males leave their mother female and establish themselves on another one nearby where they mate with newly born females, thus reducing the problems of inbreeding. If no males are present on a birthing female and virgin females are not mated in 8 to 12 days, some of the surviving females will produce parthenogenetic offspring, which are all haploid males.

Bionomics

Pyemotes tritici, the straw or hay itch mite, is an ectoparasite of various insect larvae including grain moths, peach twig borers, and many other insects. Populations of this mite may be found in stored grain, grass, and related products and their storage sites.

Public Health Significance

No disease causing agents (e.g., bacteria, viruses, etc.) are known to be transmitted by these mite species. Agricultural workers and others who handle grain, straw, or other related products are at higher risk of exposure to *Pyemotes tritici* attacks. Infested grain or other grass products are sources of mite invasions of man, which may cause extreme discomfort and lost working time.

Straw, hay, or grain itch occurs when a number of *Pyemotes tritici* bites a person causing a severe itchy skin eruption characterized by the development of vesicles which mark the site of the puncture. The lesions may itch intensely, particularly when the body warms due to exertion or lying under bed covers. The itching usually subsides in two to three days but the bite marks last longer. In some severe responses the patient may develop a fever (99 to 102°), experience accelerated heart rate, and have headache, loss of appetite, nausea, and/or mild diarrhea. In addition, symptoms of joint pains, backaches, and asthma have also been reported. Severity in response to bites from this mite species varies from person to person and may be related to the number of bites received as well. Reports of more than a thousand bites distributed anywhere on the body are in the medical literature. The arms and neck are the regions on the body most commonly attacked.

Suppression

The use of a label registered acaricide for elimination of the mites is recommended. Care must be taken when using pesticides on food products or their storage sites.

Treatment

Itching rash may be resolved with topical corticosteriod lotions or creams and oral antihistamines. If severe symptoms persist, then medical assistance should be sought.

Suborder Acaridida (= Astigmata)

Family Sarcoptidae
(Scabies Mites)

Classification - Distribution

Ten genera of sarcoptids are known to science at this time. Species of these genera (including the genus *Sarcoptes*) have been described from bats, rats, cats, cows, rabbits, horses, camels, pigs, sheep, deer, horses, dogs, monkeys, and man. Varieties or subspecies of *Sarcoptes scabiei* (DeGeer) (Fig. 17-7) are recorded from rabbits, rats, bovines, deer, camels, pigs, horses, cats, dogs, monkeys, and man. *Sarcoptes scabiei hominis* is found on humans worldwide.

General Characteristics

Sarcoptes scabiei hominis adults are broadly, oval, translucent and brownish in color; females are approximately 0.45 mm long, males 0.2 to 0.24 mm. Fine lines (striations) cover most of the body surface. The four pair of legs are very short with two pairs situated on the anterior portion of the body and two pairs on the posterior portion. The anterior two pairs of legs on the females and the males and the posterior fourth pair of legs on the males possess delicate, stalked, terminal suction pads. Spines and bristles characteristic of the subspecies are found on the dorsal body surface.

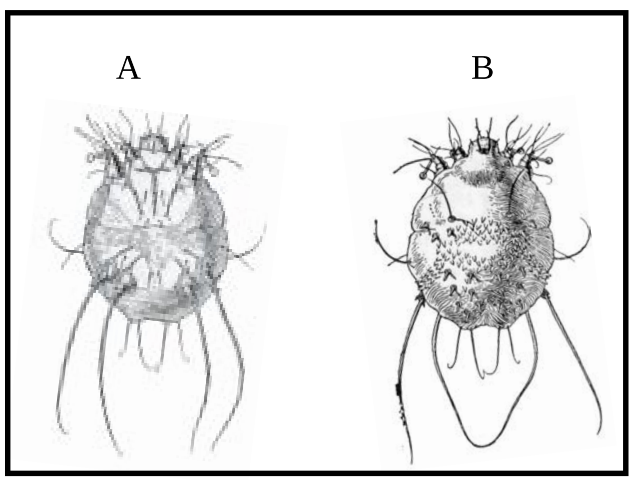

Figure 17-7. Female scabies mite, *Sarcoptes scabiei* (A. ventral view, B. dorsal view); after Mellanby, 1972.

Life Cycle

Gravid females lay their eggs on the skin surface and in excavated intradermal burrows, which may reach a length of 5 to 15 mm. It is estimated that a female lays 40 to 50 eggs during her lifetime. The eggs (on average) hatch in three days producing hexapod (six-legged) larvae. Two to three days later this feeding stage transforms into the first nymphal stage (protonymph) followed three days later by the second nymphal stage (tritonymph). The tritonymphs are sexually immature but display sexual dimorphic features and after two to four days develop into male and female adults. Copulation occurs in shallow pits in the skin after which the inseminated female burrows into and within the horny layer of the skin. The entire life cycle takes 10 to 14 days.

Bionomics

The entire life of adult *Sarcoptes scabiei hominis* is spent on its human host, usually in a burrow excavated parallel to the skin surface in the horny layer. The larvae that hatch from the eggs laid in the burrow move to the skin surface where they enter hair follicles, probably to find food. The two nymphal stages that precede the adult are also found in the hair follicles. Most mite burrows occur in the skin between the fingers and on the elbows. The skin of the scrotum, penis, breasts, knees, and buttocks is also frequently infected. Except in children, the scalp and face are rarely affected.

There are a number of records of natural *Sarcoptes scabiei* cross-transmissions between hosts of different species. In addition to these are many reports of suspected transmissions to humans from non-human hosts by *Sarcoptes scabiei*, particularly from dogs and cats. Cross-transmission experiments have been few in number but the ones done have indicated a trend supporting successful transmissions among closely related species (e.g., dogs and foxes), whereas, viable cross-transmissions have failed under normal circumstances between more distantly related species (e.g. man and dog). Rashes and other skin reactions may occur, however, when persons handle an animal infested with its particular *Sarcoptes scabiei* as seen in a number of instances with people exposed to *Sarcoptes scabiei canis* from dogs.

Public Health Significance

Scabies mites are transmitted from person to person only by close personal and prolonged contact, such as holding hands or sleeping together. Multiple infections are very common in families, dormitories, mental institutions, and nurseries. Intimate contact is necessary for transmission because the mites die quickly away from the host's body.

Increases in the incidence of scabies occur in approximately 15 to 20 year cycles, which may be due to fluctuating immunity levels in the population. Persons of all ages are affected worldwide with widespread occurrence in the tropical regions. An apparent resurgence of human scabies is happening in western countries possibly due to greater population movement and altered lifestyle patterns among young adults.

Scabies symptoms (itching, rash, etc.) usually do not present themselves until 3 to 4 weeks after the skin penetration and burrow excavation by the mites has begun. In humans, the resultant unpleasant characteristics of this disease may be caused by only a few invading female mites. Usual scabies cases have fewer than 20 mites. The intense itching and rash may typically develop around the armpits, the waist, inside the thighs, and on the back of the calves, sites that do not necessarily coincide with those of mite infection. This pervasive or widespread occurrence of itching and skin redness is the result of systemic allergic responses to mite feces, dead bodies, and other mite by-products. The severe itching may induce vigorous scratching that may break the skin and result in secondary infections (bacterial). Neglect of secondary infections may require prolonged and specialized medical treatment.

Treatment

It is important that the scabies condition be diagnosed correctly in order that proper medication be prescribed. A physician should look for the burrows of a female between the knuckles and in folds of skin of the wrist and elbows. At the end of the burrow a small dull-white spot may be seen. This object may be removed with a needle, mounted on a microscope slide, viewed under a compound microscope, and identified.

Under physicians' direction a number of medications (applied topically) have been used effectively.

The most commonly prescribed one is Kwell® (lindane). Others include Eurax® (crotamiton) and an emulsion of benzyl benzoate. The treatment of choice for children is 5 percent permethrin. In about 5 percent of scabies cases, a second course of treatment may be needed after 7 to 10 days if eggs survived the first treatment.

Suborder Acaridida
Family Acaridae

Classification - Distribution

The acarid mites are represented by a large assemblage of species, which are often found as contaminants of stored and processed food products. A species complex found commonly in stored cereals and grains is comprised of 10 species in the genus *Acarus*.

Acarus siro (the grain mite) feeds directly on a number of grains which they infest and is responsible for the "mite dust" on the surface of floors upon which wheat and flour sacks are stacked. The grain mite is found throughout temperate climates in the world but only sporadically in hot and tropical regions. Another top destructive pest of stored food products is *Tyrophagus putrescentiae* (Fig. 17-8), the mold mite, a common and worldwide contaminant of foodstuffs and a well known pest in laboratory animal cultures.

General Characteristics

Grain mites *(A. siro)* and mold mites *(T. putrescentiae)* are free-living species characterized by having a dorsal propodosomal shield and a smooth cuticle. The body setae are usually smooth, claws are well developed, the female genital opening is a longitudinal slit, and the males have anal and tarsal suckers. The enlarged femur, which bears a ventral stout spine on male *A. siro*, distinguishes this species form *T. putrescentiae.*

Life Cycle

The grain mite *(A. siro)* cycle includes a non-feeding stage specialized for dispersal and survival through extreme conditions (e.g., low humidity, high temperature). This stage is called the hypopus. The entire cycle (approximately three weeks), for *A. siro* includes an egg, larva, protonymph, hypopus, tritonymph, and adult. The *T. putrescentiae* life cycle is similar to that of *A. siro* but apparently lacks the hypopial stage. The entire lifetime for *A. siro* is approximately 40 days, during which the female lays up to 800 eggs. A similar period and egg laying capacity are assumed for the mold mite species.

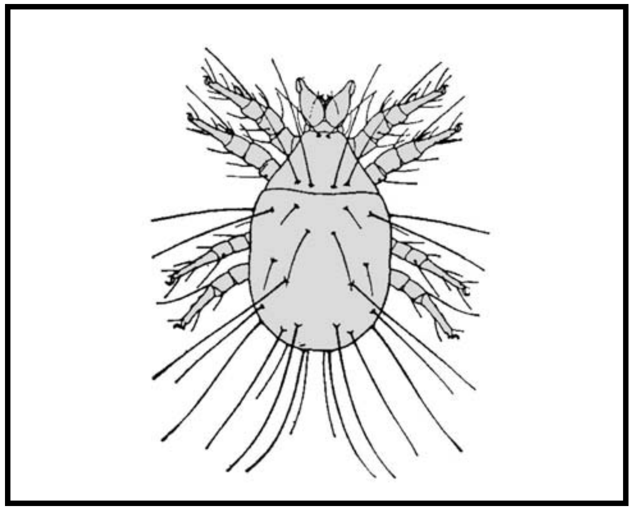

Figure 17-8. Female mold mite, *Tyrophagus putrescentiae;* after Lane and Crosskey, 1993.

Bionomics

Acarus siro is found on cheese, grain, hay, linseed, barley, abandoned bee hives, and flour. The distribution of *A. siro* in stored food products is determined by the relative humidity (R.H.). This species prefers R.H. conditions between 75 and 85 percent. Fungi infested grains are attractive to grain mites and also serve as food sources as well. *Tyrophagus putrescentiae* is found most often in stored food products containing high fat and protein. These foodstuffs may include dried egg, cheese, ham, ground nuts, linseed, dried banana, wheat spillage, barley, oats, and different flours. The mold mite species feeds largely on fungi.

Both grain mites and mold mites have been collected from natural habitats including pasture and grass lands. *Acarus siro* is also commonly found in bird nests and it is thought that birds are important in its dispersal.

Public Health Significance

Both species of mites are common in grocery stores and are often the responsible agents for the dermatitis referred to as "grocers itch." Rodents, birds, and humans (on shoes and clothing) are probably important dispersal factors to new locations.

"Grocers itch" is seen as generalized skin inflammation (dermatitis) that may result from contact with food infested by acarid mites. The cause of the dermatitis has been attributed to the "dust" generated by the mites, the microbes present in the "dust," or a substance found in the saliva of the mites.

Suppression

Treatment of the foodstuffs is recommended initially in the field and in storage facilities using appropriate materials and techniques. Some mite infestations of packaged or canned food may originate in processing or storage sites. Therefore, broken packages or damaged cans should not be purchased. Infestations are most likely to happen in opened packages that are left unsealed for long periods. Control of these mite invasions requires that all sources of infestation be located and destroyed. Newly purchased foodstuffs should be stored in seal-tight containers. Under certain conditions label-approved acaricides (pesticides) may be used. Prevention of acarid mite infestation may be attained by maintaining low relative humidity foodstuff storage rooms.

Treatment

The dermatitis condition in people is self limiting once the source (the mites) has been removed. Physician-prescribed lotions or ointments for itching and swelling may be appropriate.

Suborder Acaridida

Family Glycyphagidae

Classification - Distribution

Seven genera of mites are known in this family and all of its species are associated with dried vegetable matter. Most are found in grains, seeds, and other stored, often fungus infested, foodstuffs. A few have been consistently collected from bird nests or bat roosts. Two species of *Glycyphagus* Hering, *Glycyphagus domesticus* DeGeer and *Glycyphagus destructor* (Schrank) (Fig. 17-9), are found commonly in stored food products worldwide.

General Characteristics

The species of *Glycyphagus* are characterized by having a rough body covering (integument), body and leg setae (hairs) with many tiny projections, and long tapering legs. The male genital opening is between coxae III; genital sense organs are present on both sexes. No anal or tarsal suckers are present on the male.

Life Cycle

Both species of *Glycyphagus* proceed through the same life cycle: egg, larva, protonymph, active deutonymph or hypopus, and adult. Under conditions of 73 to 77°F and a relative humidity of 80 to 90 percent, *G. domesticus* completes its life cycle in 22 days.

Bionomics

Glycyphagus destructor is one of the most common species found in stored food products and is often collected in association with grain mites *(Acarus siro)*. This species lives in stores of cereal, grain, dried fruit, hay, cheese, straw, and rodent and bumble bee nests, and is strictly a fungus feeding mite. *Glycyphagus domesticus* occurs on dried animal and plant remains in buildings. It has also been found in bulk stores of wheat, sugar, flour, hay, tobacco, and in bees' and birds' nests. The optimal environment for *G. domesticus* is one in which the temperature ranges

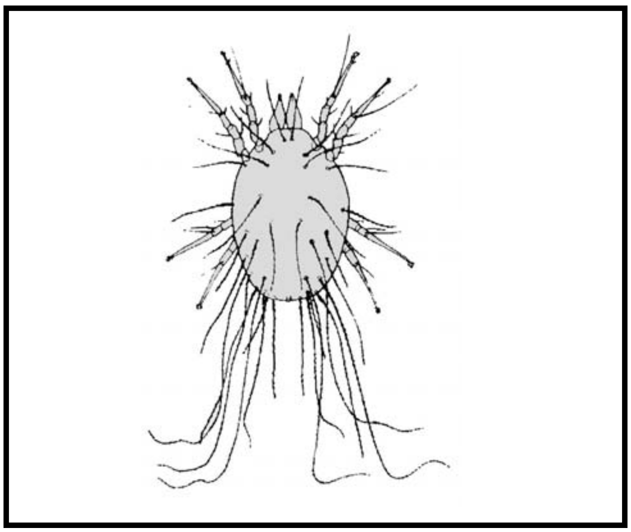

Figure 17-9. Female cheese mite, *Glycyphagus destructor;* after Lane and Crosskey, 1993.

from 73 to 77°F and the relative humidity ranges from 80 to 90 percent. Up to 50 percent of the protonymphs become hypopi, which are resistant to prolonged dry conditions, and may remain in this stage up to six months.

Public Health Significance

Glycyphagus domesticus, in common with the acarid mites, *Acarus siro* and *Tyrophagus putrescentiae,* has been implicated as a causative agent of "grocers itch." Refer to the acarid mites *(A. siro and T. putrescentiae)* section for more information.

Suppression and Treatment

Same as indicated for acarid mites.

Suborder Acaridida

Family Pyroglyphidae

(House Dust Mites)

Classification-Distribution

The family Pyroglyphidae contains five genera including *Dermatophagoides*, which has species of considerable medical importance. *Dermatophagoides pteronyssinus* (Fig. 17-10), the European house dust mite, and *Dermatophagoides farinae*, the American house dust mite, are the most impacting species on human health and are cosmopolitan in distribution.

General Characteristics

The mites are small; adult females are about 0.5 mm in length. Legs III - IV of the female are without long terminal setae. These mites are found in the nests of mammals or birds, or free-living in dust and debris of buildings and other structures.

Life Cycle

The species of *Dermatophagoides* and other pyroglyphid mites have five distinct life stages: egg, larva, protonymph, tritonymph, and adult. For *D. farinae* and *D. pteronyssinus*, the developmental period from egg to adult ranges from 23 to 30 days. Pyroglyphids are not parthenogenetic, i.e., they do not produce viable eggs without mating. On average, females lay three eggs per day. Eggs hatch in six to twelve days, depending upon the ambient temperature. The larva hatches from the egg, actively feeds for about six days, then enters a quiescent (inactive) stage for three days. A protonymph emerges, feeds, and the resulting inactive stage molts to an active tritonymphal stage (5 days). The inactive stage produced by the tritonymph molts to the final adult stage. Adults live about two months and mated females oviposit 200 to 300 eggs.

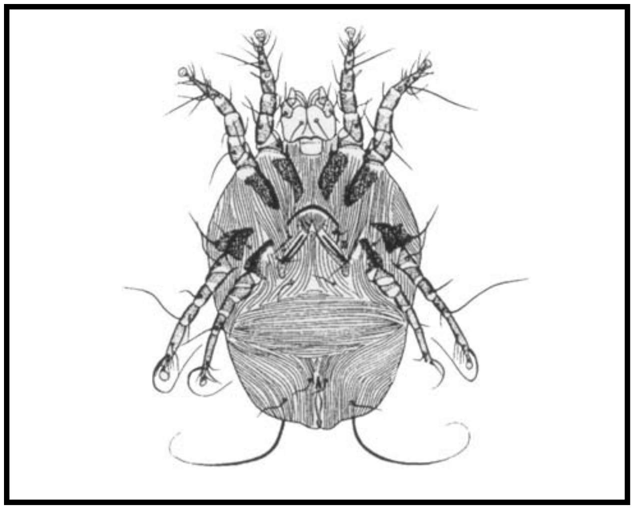

Figure 17-10. Female house dust mite (ventral view), *Dermatophagoides pteronyssinus;* after Lane and Crosskey, 1993.

Bionomics

House dust mites are found principally in cotton-stuffed furniture and mattresses. Mites are rare or absent in furniture pieces that are not stuffed with vegetable fibers and are unused by people. It is believed that *Dermatophagoides* species feed primarily on skin scales from humans and their pets; however their guts were found to contain pollen, bacteria, fungi, and fibers as well. These mite species are very sensitive to low humidity conditions and thrive best in relative humidity environments of 75 to 95 percent.

Public Health Significance

Dermatophagoides pteronyssinus and *D. farinae* are the mites most frequently encountered in house dust. They are common in beds, blankets, pillows, floor rugs, and carpets where they feed on shed human skin. Many household activities, e.g. bedmaking, sweeping, and cleaning, cause the mites and related materials to become airborne. Consequently, they are easily inhaled into the respiratory tract where allergic reactions occur resulting in long term allergy problems. House dust mites (dead or alive), their fragments, and feces are allergenic, i.e., they cause significant allergic responses in many susceptible people. As a result, inflammation of the sinuses and nose (rhinitis) and asthmatic conditions develop in some individuals who have chronic exposure to dust mites. Although reported to cause severe and persistent dermatitis (skin irritation), *D. scheremetewskyi*, has been determined to be *D. pteronyssinus* and not to be parasitic on humans or other animals.

Suppression

Environmental mite control should be attempted in homes where sensitive people live. Good housekeeping done on a regular and frequent schedule including intensive vacuuming of all rooms with particular attention paid to the bedrooms and cracks and crevices. At least once a week floors, furniture, bedding, and clothes should be cleaned. Vacuum cleaning and airing out of mattresses is also recommended.

Treatment

Desensitization by intradermal injections of sequentially increased mite extract concentrations administered by an allergist has been successful in a significant number of mite sensitive individuals.

Order Parasitiformes

Suborder Gamasida (= Mesostigmata)

Family Macronyssidae

Classification - Distribution

Macronyssid mites are blood-feeding species found worldwide on birds, mammals and reptiles. Three medically important species of *Ornithonyssus* Sambon reflect this global distribution pattern. *Ornithonyssus bacoti* is commonly referred to as the Tropical Rat Mite; *O. bursa* is called the Tropical Fowl Mite; and *O. sylviarum* is known as the Northern Fowl Mite (Fig. 17-11).

General Characteristics

Females of all three species have mouth parts (chelicerae) modified for piercing and sucking; blood feeding. Females also have a single dorsal plate and a single rectangular sternal plate with 2-3 pairs of setae on the sternal plate. All coxae in both males and females lack ventral spurs or spines. The male holoventral plate is entire and does not extend beyond the last pair of coxae (coxae IV). The femur of the male pedipalp usually possesses a prominent seta on a noticeable elevation.

Life Cycle

Adult *Ornithonyssus* spp. mites consist of both male and female individuals. After mating the females lay eggs which hatch into 6-legged larvae. The larval stage transforms into the first of three nymphal stages, which are 8-legged and sexually immature. The first nymphal stage is called the protonymph, the second is referred to as the deutonymph, and the third is the tritonymph.

The following is a summarized life cycle of the tropical rat mite *(O. bacoti)*, which generally parallels those of *O. sylviarum* and *O. bursa*. The life cycle of *O. bacoti* includes the egg stage, nonfeeding larva, blood-feeding protonymph, nonfeeding deutonymph, and male and female sexually mature adults. Both the protonymph and the adult stages must have a blood meal in order to complete the cycle. Unfertilized females reproduce by parthenogenesis producing male offspring. Development time from egg to adult ranges from 7 to 16 days at room temperatures (68-72° F). Adult females, which live an average of 60 days produce several batches of eggs averaging about 100 eggs per female. In absence of their murine hosts the tropical rat mites usually die off in two to three weeks. The bird mites *(O. sylviarum* and *O. bursa)* usually cannot exist for more than 10-14 days apart from their avian host.

Bionomics

The tropical rat mite *(O. bacoti)* is a parasite of roof rats *(Rattus rattus)* and Norway rats *(Rattus norvegicus)*, which are commensal rodent species found in association with human industry and living accommodations worldwide. Many collection records are known of *O. bacoti* from a wide variety of mammals including numerous ones from sylvan rodents and also a few from sciurid species, rabbits, skunks, and foxes. A small number of records have been listed of *O. sylviarum* from mammals including bats, squirrels and mice. *Ornithonyssus bursa* has rarely been recorded from hosts other than birds.

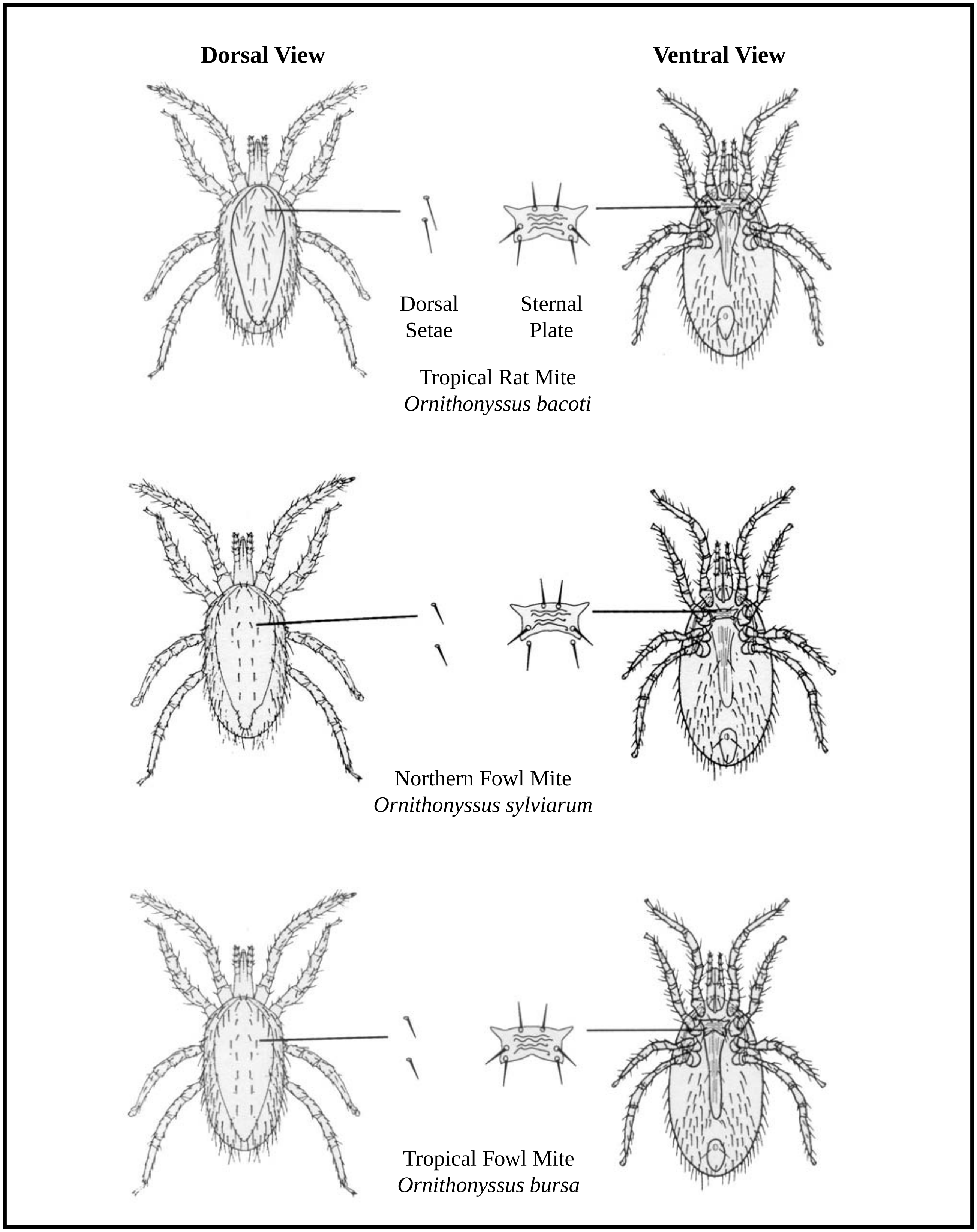

Figure 17-11. Mites (Family Macronyssidae).

Ornithonyssus sylviarum occurs throughout the temperate regions of the world and is typically found on domestic fowl with many records also known from many wild bird species. Recovery of northern fowl mites from buildings is often correlated with infested bird nests constructed in the eaves of the building.

The tropical fowl mite *(O. bursa)* is distributed throughout the warmer regions of the world and is associated mainly with poultry, pigeons, and sparrows.

Adult northern fowl mites *(O. sylviarum)* spend most of their lives on the avian host, whereas some of the adults and the other life stages are found in the nesting material. The life stages of *O. bacoti* and *O. bursa* predominantly inhabit the nests of their hosts with intermittent feeding forays made by the nymphs and adults.

Public Health Significance

A number of microbial and viral pathogens have been shown to be isolated from and/or experimentally transmitted by *O. bacoti*, including ones that cause murine typhus, tularemia, and plague. In addition, western equine encephalitis and Newcastle disease viruses have been recovered from *O. sylviarum*. None of these microbes or viruses has demonstrated persistent infection or transmission and is thought not to represent any significant disease threat. These two species and *O. bursa,* however, have been implicated numerous times with bite attacks on people causing severe irritation and painful dermatitis. Reports are also known of heavy *O. bursa* and *O. sylviarum* infestations of chickens resulting in weight loss, decreased egg production, and even death through loss of blood.

Suppression

Rodent control is the best method of avoiding tropical rat mite *(O. bacoti)* infestations. Prevention of *O. bacoti* invasions after rat extermination programs may be accomplished by using label-sanctioned acaricides. Control of *O. bursa* and *O. sylviarum* infestations may also be achieved by removing suspect bird nests and by using approved acaricides and following label instructions closely.

Treatment

Treatment involves alleviation of the symptoms and eradication of the mites from the home or workplace. Topical corticosteriod lotions and creams are recommended to reduce dermal inflammation, and oral antihistamines are suggested for relief of itching and burning.

Suborder Gamasida

Family Dermanyssidae

(Chicken Mites)

Classification - Distribution

The most currently accepted classification of this family of mites includes many free-living species and a number of ectoparasitic species. One species, *Dermanyssus gallinae* (Fig. 17-12), the chicken mite, is the only one of the group of known medical and economic importance. The chicken mite is cosmopolitan in distribution.

General Characteristics

Dermanyssids are medium-sized mites. The sternal plate on the female is reduced in size and arch-shaped with three pairs of setae. The female dorsal plate is usually undivided. The chelicerae in some dermanyssids (Genus *Dermanyssus*) are elongate and needle-like, an adaptation for piercing and sucking, e.g., blood feeding. The genito-ventral plate is drop-shaped posteriorly and the anal plate has three setae. The holoventral plate of the male extends slightly behind the posterior pair of coxae (coxae IV).

Life Cycle

The life cycle of *Dermanyssus gallinae* consists of an adult male and female, egg, larva, protonymph, and deutonymph. Under optimal conditions the entire cycle may only require seven days.

Bionomics

The female *D. gallinae* lays her eggs in cracks and crevices or under debris in chicken houses or in bird nests. Both poultry roosts or bird nests may be sources of home infestations and attacks on the human and pet occupants. After a blood meal the mites become longer in size and bright red in color.

Public Health Significance

Although St. Louis encephalitis (SLE) virus has been recovered from laboratory-infected *D. gallinae*

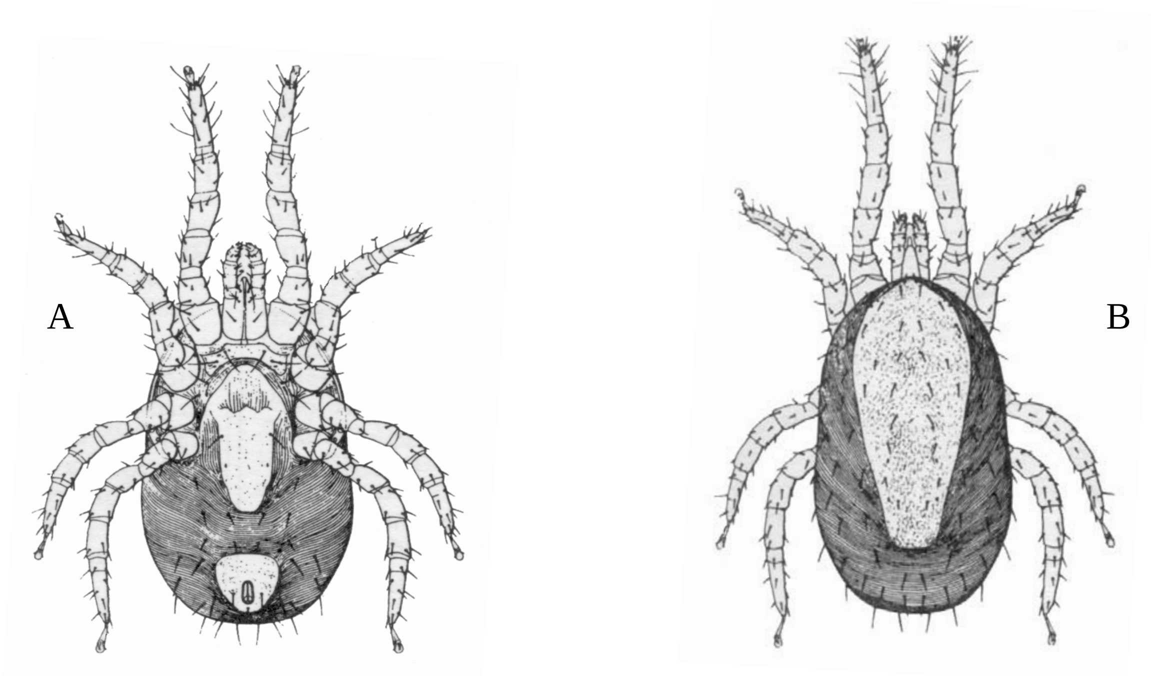

Figure 17-12. Female chicken mite, *Dermanyssus gallinae* (A. ventral view, B. dorsal view); after Yunker, 1973.

and eastern equine encephalitis (EEE) and western equine encephalitis (WEE) viruses have been isolated from wild-caught chicken mites, researchers conclude that *D. gallinae* is of no importance as a vector or reservoir of these viruses in nature. This species is one of the most common ones that causes painful skin irritation found in association with farms, ranches, poultry houses, and live chicken markets.

Suppression

Chicken mite infestations of office buildings, schools, and homes can often be tracked to bird nests located under the eaves or in the attic. The removal of the nest in addition to the application of an appropriate acaricidal pesticide usually eliminates the mite problem. Quality construction and efficient maintenance of poultry houses as well as the use of approved acaricides will control mite infestations of chickens and other poultry species.

Treatment

Sensitive people may develop dermatitis, which may be treated with topically applied corticosteriods and oral antihistamines to relieve burning and itching.

Acknowledgements

Our sincere gratitude is extended to Mr. Minoo B. Madon, Technical Director, Greater Los Angeles County Vector Control District, and to Dr. Richard P. Meyer, Assistant Manager, Orange County Vector Control District (OCVCD), for critical review of and recommendations for the original manuscript. We also thank Dr. Robert D. Sjogren, Manager, OCVCD, for administrative support, and also Mrs. Justine Keller, OCVCD, for editorial and clerical assistance.

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CHAPTER 18

TICKS

Robert S. Lane[1] and James R. Clover[2]

GENERAL CHARACTERISTICS

Ticks are bloodsucking ectoparasites of reptiles, birds, mammals, and rarely, amphibians. Unfed ticks are dorsoventrally flattened, leathery-like, six (larvae) or eight-legged (nymphs, adults) arthropods that range in length from <1 to 30 mm. Some of their distinguishing features include a hold-fast structure, the hypostome, which is armed with retrorse teeth; Haller's organ, a sensory setal field situated dorsally on tarsus I in both subadults and adults; spiracular plates present in nymphs and adults; palpi three- or four-segmented; and chelicerae two-segmented. Argasids (soft ticks) and ixodids (hard ticks) differ morphologically in several important characteristics (Figs. 18-1, 18-2). Among the argasids, for instance, sexual dimorphism is slight (versus pronounced in ixodids); the capitulum (gnathosoma) is situated anteroventrally (versus anteriorly in ixodids); and the scutum, a prominent dorsal sclerotized plate, is absent (versus present in ixodids). Ixodids and argasids are referred to respectively as hard-bodied and soft-bodied ticks because of the presence or absence of the scutum. The reader is referred to Oliver (1989) and Sonenshine (1991) for comprehensive treatments of the biology of ticks, including their evolutionary and systematic relationships. The literature review for this chapter was completed largely by mid-1997.

BIONOMICS

Soft ticks are normally associated with the burrows or other microhabitats frequented by their primary vertebrate hosts. Both immature and adult soft ticks usually feed to repletion rapidly, i.e., typically within minutes or at most one to two hours. Unlike hard ticks, female soft ticks may feed and oviposit several times. Most species usually lay from a few hundred to over 1,200 eggs during their lifetime. Mating takes place off the host. Larvae and nymphs of a few species do not feed prior to molting.

Slightly over 90% of hard-tick species undergo a three-host life cycle in which the larva, nymph, and adult each feed on a different vertebrate belonging to the same or two to three different species. The remaining species exhibit either a two- or one-host life cycle. In the case of the former, the larva and nymph feed on the same individual animal, whereas, the adult feeds on a second host. All three parasitic stages of one-host ticks feed on the same individual animal. Following attachment, most hard ticks require several days to a week or longer to feed to repletion with rapid engorgement occurring late during the feeding process. Immatures and adults feed only once, but under unusual circumstances, hard ticks may take a partial blood meal from one host and reattach to another host (e.g., after the death of the first host). Mating can occur either on or off the host. Females of many species lay 1,000 to several thousand eggs and some free-ranging species may deposit up to 18,000 eggs. Parthenogenesis, reproduction without fertilization of the ovum, has been reported for several species, including *Ixodes jellisoni* from California. Certain species of ixodids are closely associated with the burrows or nests of their hosts, whereas, some three-host ticks are scattered widely throughout the geographic range of their primary hosts.

PUBLIC HEALTH SIGNIFICANCE

Ticks are of public health significance because (1) their attachments may cause various kinds of skin disorders (e.g., abnormal redness, pain, swelling); (2) they rarely may invade the auditory canal of humans producing a condition known as otoacariasis; (3) females of certain ixodids can cause a flaccid, ascending, and sometimes fatal paralysis known as tick paralysis; (4) individuals bitten repeatedly by some ticks may develop allergic

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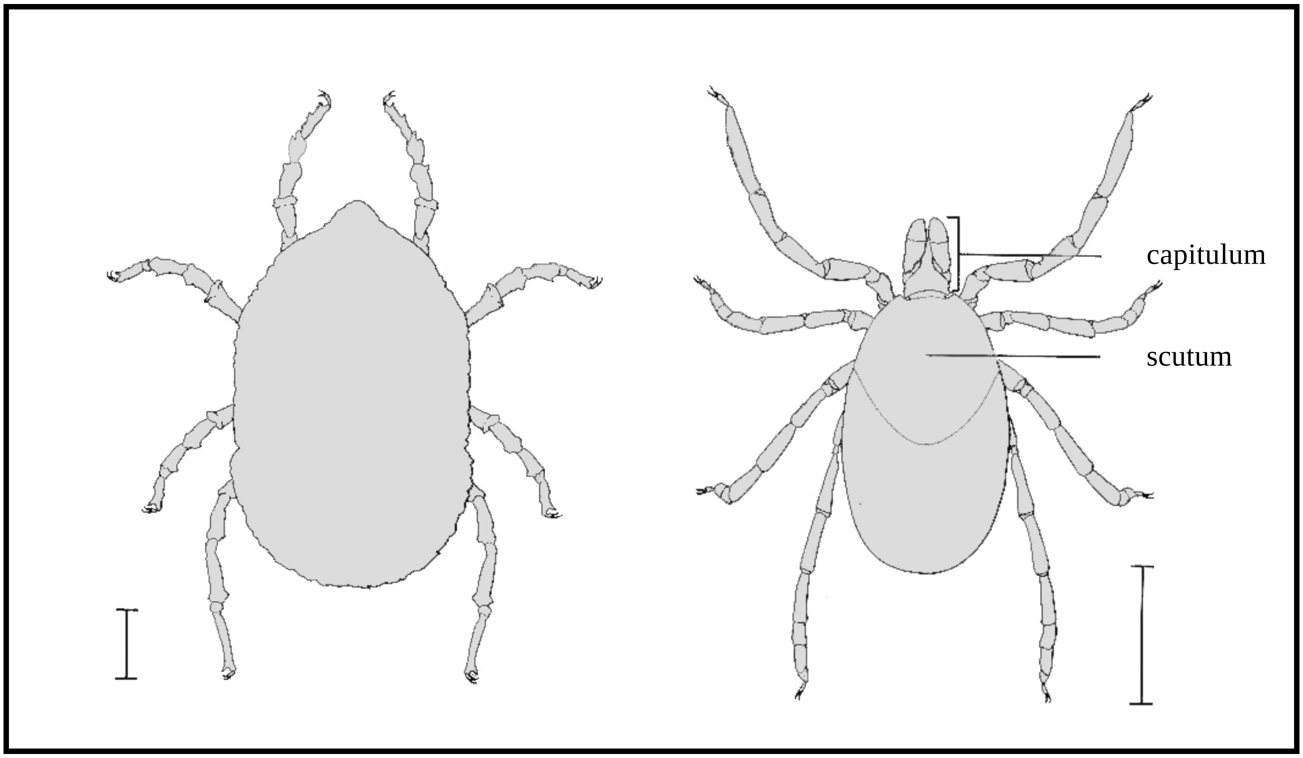

Figure 18-1. The soft tick *Ornithodoros coriaceus* (left) and a female of the hard tick *Ixodes pacificus* (right). Note the absence of an anteriorally-projecting capitulum and a scutum in *O. coriaceus* versus their presence in *I. pacificus*. Vertical bars indicate 1 mm.

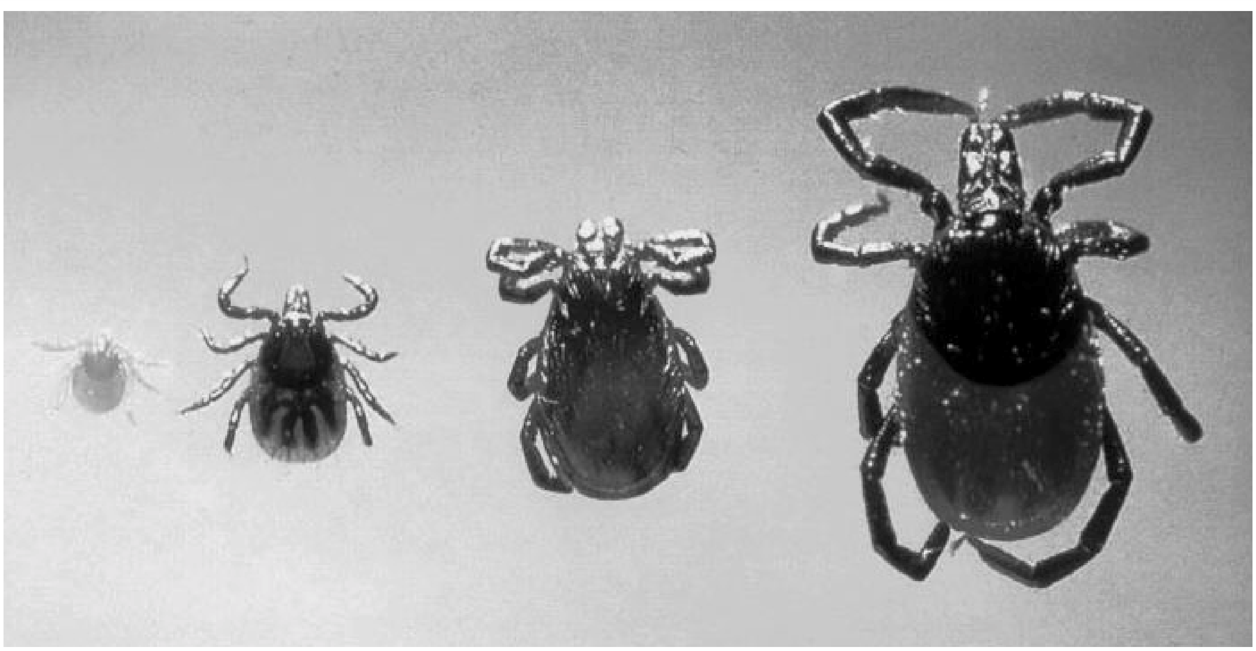

Figure 18-2. The larva, nymph, male and female of *Ixodes pacificus* (from left to right). Photograph courtesy of the former Scientific Photographic Laboratory, University of California, Berkeley.

or even anaphylactic reactions; and most importantly, (5) they transmit numerous bacterial (including rickettsial), viral, and protozoan disease agents.

In California, six species of ticks are of considerable public health significance either because of the reactions produced by their bites or their ability to transmit one or more microbial disease agents to humans. These include two soft ticks, *Ornithodoros hermsi* and the pajahuello tick (*Ornithodoros coriaceus*), and four hard ticks, the Rocky Mountain wood tick (*Dermacentor andersoni*), the Pacific Coast tick (*Dermacentor occidentalis*), the American dog tick (*Dermacentor variabilis*), and the western black-legged tick (*Ixodes pacificus*). Of these, *I. pacificus* (Fig. 18-2) and *O. coriaceus* (Fig. 18-1) are notorious for the persistent dermatoses they produce in susceptible individuals. The reddish, expanding lesions that sometimes result from the attachment of *I. pacificus* in persons previously sensitized to its bite (Fig. 18-3) may be confused with erythema migrans (Fig. 18-4), the best clinical marker for early stage Lyme disease.

The nymphs and adults of both *O. hermsi* and *O. coriaceus* attack humans. Among the *Dermacentor* spp., the adults of *D. andersoni* and *D. variabilis* and the larvae, nymphs, and particularly the adults of *D. occidentalis*, bite people. The nymphs and adult females of *I. pacificus* commonly attach to humans, whereas the larvae and adult males rarely bite this host.

For a detailed description of all six tick species and a summary of their geographic distributions, biologies, and public health/veterinary importance in California, the reader is directed to the excellent monograph by Furman and Loomis (1984).

Other tick species also occasionally bite humans in California, but their role as human pests or vectors of disease agents is inconsequential compared to the foregoing species. For example, the brown dog tick (*Rhipicephalus sanguineus*), an important ectoparasite of dogs, particularly in large population centers, infrequently attacks humans or birds (Furman and Loomis 1984).

Tick-Borne Diseases

In the United States, ticks are known to transmit 14 human pathogens, including nine bacteria (*Borrelia burgdorferi*, *Borrelia hermsii*, *Borrelia parkeri*, *Borrelia*

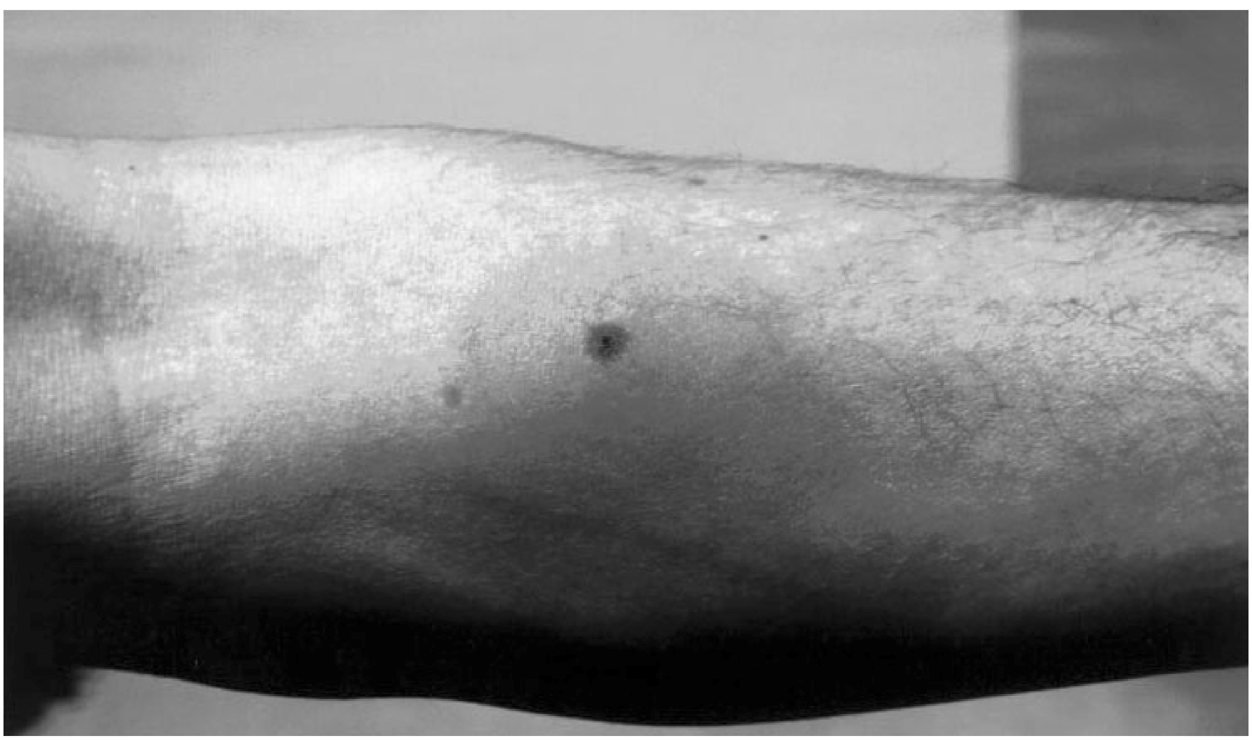

Figure 18-3. Allergic reaction to the attachment of *Ixodes pacificus* in an individual bitten previously by this tick species.

Figure 18-4. Erythema migrans, the skin rash common in early stage Lyme disease. Photograph courtesy of Ross Ritter, Potter Valley, CA.

turicatae, Coxiella burnetii, Ehrlichia chaffeensis, Ehrlichia sp. near *equi, Francisella tularensis,* and *Rickettsia rickettsii*), two viruses (Colorado tick fever virus, Powassan encephalitis virus), and three protozoans (*Babesia microti, Babesia* sp. [WA1], *Babesia* sp. near *divergens*) (Table 18-1). The two agents that reportedly infect humans most often are the Lyme disease spirochete, *B. burgdorferi* (Fig. 18-5), and the rickettsia that causes Rocky Mountain Spotted Fever (RMSF), *R. rickettsii*. Lyme disease now comprises over 90% of all vector-borne illnesses reported nationwide; indeed, 48 states recorded 68,839 cases of the disease between 1991 and 1996. RMSF was the most commonly reported vector-borne disease during the 1970s and currently ranks second in terms of morbidity and first in case-fatality rates. About 1-5% of the individuals presently afflicted annually with RMSF die despite the availability of effective antibiotics for treating it.

Conversely, other North American tick-borne agents, such as Powassan encephalitis virus and *Borrelia parkeri*,

Figure 18-5. Direct fluorescent antibody staining of Lyme disease spirochetes in the midgut of an *Ixodes pacificus* tick.

infect humans infrequently or under extraordinary circumstances. Although the montane relapsing fever spirochete *B. hermsii* has been responsible for hundreds of cases in California since the disease was made reportable in 1931, the related relapsing fever spirochete, *B. parkeri*, seldom infects humans. One cluster of relapsing fever cases was traced to exposure in sandy caves in Stanislaus County where *O. parkeri*, presumably infected with *B. parkeri*, was found to be the source of infection. In contrast to *O. hermsi*, which normally transmits *B. hermsii* spirochetes to persons as they sleep in summer cabins or cottages, *O. parkeri* inhabits the burrows of rodents (e.g., ground squirrels) and, therefore, infrequently has an opportunity to feed upon and infect people with *B. parkeri*. The three species of North American relapsing-fever spirochetes (*B. hermsii*, *B. parkeri*, *B. turicatae*) are treated collectively here because they cause a similar clinical entity.

Limited clinical and serologic evidence suggest that another species of *Borrelia* isolated from the soft tick, *O. coriaceus*, may sometimes infect people in California. This spirochete, named *B. coriaceae* after its tick vector, also has been suspected of being the etiologic agent of epizootic bovine abortion, an important disease of rangeland cattle in California.

California is unique among the United States, not only for the diversity of its tick fauna (48 spp.), but for the variety of tick-borne microbial agents as well. All of the diseases listed in Table 18-1 reportedly occur in California except for Powassan encephalitis. Although no human cases of Powassan encephalitis have been reported from the state, the causative virus was isolated from a spotted skunk in Sonoma County. Additionally, several characterized and uncharacterized spotted fever group (SFG) rickettsiae and one typhus group rickettsia, *Rickettsia canada*, have been isolated from hard ticks in California. Of these, only one unclassified SFG rickettsia, designated 364-D, has been implicated as a

Table 18-1. Tick-borne diseases in the United States.

Disease (Agent)	Geographical Distribution	Primary Vertebrate Hosts or Reservoirs	Tick Vectors	Agent-Vector Relationship and Transmission Routes
Babesiosis				
(*Babesia microti*)	Most cases occur on coastal islands in the Northeast; sporadic cases occur elsewhere (e.g., Connecticut, Massachusetts, Wisconsin)	*Peromyscus leucopus*	*Ixodes scapularis**	Transstadial Transmitted by bite
(*Babesia* sp.)**	California, Washington State	Deer (*Odocoileus hemionus*)	Unknown	Unknown
(*Babesia* sp. near *divergens*)	Missouri	Unknown	Unknown	Unknown
Ehrlichiosis				
Human monocytic ehrlichiosis (*Ehrlichia chaffeensis*)	Primarily in southeastern and south central states, occasionally in California	Deer (*Odocoileus* spp.)	*Amblyomma americanum*, possibly *D. variabilis* and *I. pacificus*	Unknown
Human granulocytic ehrlichiosis (*Ehrlichia* sp. near *equi* and *phagocytophila*)***	Upper Midwest, Northeast, California	*P. leucopus* *Neotoma fuscipes*	*I. scapularis*, *I. pacificus*	Transstadial Transmitted by bite
Tularemia (*Francisella tularensis*)	Widespread, including California; most cases occur in central states (Arkansas, Missouri)	*Microtus* spp. *Peromyscus* spp. *Spermophilus* spp. beaver lagomorphs muskrat, sheep	*A. americanum* 5 *Dermacentor* spp. 2 *Haemaphysalis* spp. 5 *Ixodes* spp.	Transstadial Transmitted by bite (ticks, deer flies, mosquitoes) Handling infected animals Dust, Meat, Water

Table 18-1. continued.

Disease (Agent)	Geographical Distribution	Primary Vertebrate Hosts or Reservoirs	Tick Vectors	Agent-Vector Relationship and Transmission Routes
Lyme disease (*Borrelia burgdorferi*)	Most cases occur in Northeast, upper Midwest, and northern California	Rodents (e.g., *Peromyscus* spp., kangaroo rats, woodrats) Lagomorphs, lizards, deer	*I. scapularis* *I. pacificus* *I. dentatus* *I. spinipalpis***** *A. americanum* (?)	Transstadial Transovarial (rare) Transmitted by bite
Tick-borne relapsing fever *(Borrelia hermsii, parkeri, turicatae)*	Western U.S., including California	Rodents	*Ornithodoros hermsi* *O. parkeri* *O. turicata*	Transstadial Transovarial (except in *O. parkeri*)
Rocky Mountain spotted fever (*Rickettsia rickettsii*)	Widespread, including California; ~98% of human cases occur in eastern states	Lagomorphs Rodents	*D. andersoni* *D. occidentalis* *D. parumapertus* *D. variabilis* *A. americanum* *Haemaphysalis leporispalustris*	Transstadial Transovarial Transmitted by bite
Q-fever (*Coxiella burnetii*)	Endemic in California and several other states	Sheep, cattle, deer Medium-sized mammals (e.g., fox, coyote, lagomorphs, skunk) Rodents	Many species of ixodid and argasid ticks	Transstadial Transovarial in some ticks Transmitted by bite experimentally Contaminated dust Raw milk
Colorado tick fever (virus: genus *Coltivirus*, family Reoviridae)	Western U.S., including California	Lagomorphs Rodents (e.g., *Tamias*, *Spermophilus*)	*Dermacentor andersoni* 6 other species have been found infected naturally	Transstadial Transmitted by bite
Powassan encephalitis (virus: genus *Flavivirus*, family Togaviridae)	Northern U.S., and California; human cases are rare	Wild rodents, lagomorphs raccoons, foxes, skunk groundhog	*Dermacentor andersoni* *Ixodes* spp.	Transstadial Transmitted by bite

***** Formerly *I. dammini* in part.
****** First detected in Washington State and designated WA1.
******* Designated *Anaplasma phagocytophila* in 2001.
**** Formerly *I. neotomae*.

cause of human disease. This rickettsia is closely related to, but distinct from, typical strains of *R. rickettsii* that cause RMSF.

Lyme disease is the most commonly reported vector-borne disease in California, where it currently accounts for about 90% of such cases. The first recognized case involved an individual who had been bitten by a tick while hiking in Sonoma County in 1975. Surveillance for the disease was initiated in 1983 by the Infectious Disease Branch, California Department of Health Services. However, Lyme disease was not made officially reportable in this state until March 1989.

The first isolate of *B. burgdorferi* from western North America was obtained from an adult western black-legged tick, *I. pacificus*, collected in the Hopland area of Mendocino County, California, in 1984. Since then, *B. burgdorferi* has been isolated from *I. pacificus* in 41 of the 58 counties within this state (California Department of Health Services, unpubl. data.). *Ixodes pacificus* is an important vector to humans with the prevalence of spirochetal infection usually averaging about 5 to 15% in nymphs versus 1 to 4% in adults. The highest prevalence of infection, 41.3%, was recorded for *I. pacificus* nymphs that inhabited a hardwood forest near Ukiah, California. Several other species of hard ticks have been found infected naturally with *B. burgdorferi* in California, including *Ixodes spinipalpis* (formerly *I. neotomae*), an efficient enzootic (maintenance) vector. This tick feeds predominantly on rodents and lagomorphs. Recent molecular and morphologic data gathered by Douglas E. Norris and co-workers indicate that *I. neotomae* is conspecific with, and therefore is a synonym of, *I. spinipalpis*. Two species of rodents, the dusky-footed woodrat (*Neotoma fuscipes*) and the California kangaroo rat *(Dipodomys californicus*), have been identified as primary reservoirs of *B. burgdorferi* or closely related spirochetes (Figs. 18-6, 18-7). These rodents can infect up to nearly 40-50% of noninfected *I. pacificus* larvae that feed on them. Deer mice (*Peromyscus* spp.) apparently serve as secondary reservoirs in some areas and, in the absence of woodrats or kangaroo rats, may serve as primary reservoir hosts.

Human Diseases Associated with Ticks Occurring in California

Five of the six medically important ticks in California transmit either one or more microbial disease agents to humans. *Ornithodoros coriaceus* is the only exception with no known pathogens transmitted by this tick; the ability of its associated spirochete, *Borrelia coriaceae*, to infect and cause illness in humans awaits clarification. Diseases associated with the other five tick species are as follows.

The primary vector of the relapsing fever spirochete, *B. hermsii*, is the soft tick, *O. hermsi*, which occurs mainly at elevations of $\geq$ 5,000 feet (1,524 m). The Rocky Mountain wood tick, *D. andersoni*, is the principal vector of Colorado Tick Fever (CTF) virus and *R. rickettsii* in the western United States. The etiologic agents of Q fever, tularemia, and Powassan encephalitis also have been recovered from *D. andersoni*, and this tick is the most important cause of tick paralysis in the Pacific Northwest. Curiously, no cases of tick paralysis have been attributed to this tick in California. The Pacific Coast tick, *D. occidentalis*, has been associated with the same human disease agents as *D. andersoni* with the exception of Powassan encephalitis virus. Also, it has rarely been found infected with *B. burgdorferi*. The American dog tick, *D. variabilis*, is the primary vector of *R. rickettsii* in the eastern United States, a competent vector of *F. tularensis*, and a cause of tick paralysis in humans in the East. *Dermacentor variabilis* is not known to either cause paralysis or transmit microbial disease agents to humans in California even though it is infected occasionally with *B. burgdorferi*. Besides being a competent vector of the Lyme disease spirochete, *I. pacificus* has been found infected with *F. tularensis* in Oregon. Occasionally its bite may induce anaphylaxis and a mild form of tick paralysis in humans. Recent experimental evidence demonstrated that *I. pacificus* can transmit *Ehrlichia equi*, the agent of equine ehrlichiosis, from infected to susceptible horses. This rickettsia is closely related to, if not identical with, the agent of human granulocytic ehrlichiosis. For further information about these diseases, the reader is referred to Harwood and James (1979), Furman and Loomis (1984), Sonenshine (1993), and Lane (1994).

Emerging Tick-Borne Diseases in California

Since the early 1990s, several cases of human babesiosis (caused by an apparently new species of *Babesia* first identified in Washington State and designated WA1), human monocytic ehrlichiosis (HME) (caused by *Ehrlichia chaffeensis*), and human granulocytic ehrlichiosis (HGE) (caused by an *Ehrlichia* species closely related to *E. equi* and *E. phagocytophila*)

Figure 18-6. The dusky-footed wood rat (*Neotoma fuscipes*), a primary reservoir of *Borrelia burgdorferi* sensu lato spirochetes in California. Photograph courtesy of Robert Keiffer, Hopland, CA.

have been reported in California. *Ixodes pacificus* has been implicated as the primary vector of the HGE agent, but the principal vectors of the agents of HME and of human babesiosis have not been identified as of mid 1997. Studies presently are underway to elucidate the etiologic agents, the full clinical spectrum, and the ecology and epidemiology of these "emerging" zoonotic diseases.

Vector Suppression

Control measures directed against ticks consist of any method or combination of methods, which either interrupt or minimize contact between a tick and its host. Conventional control measures using pesticides can be integrated with natural controls, avoidance procedures, personal protection techniques, and environmental modification to reduce the likelihood of human exposure to ticks. Control strategies vary considerably according to the species of tick targeted, its life stage, habitat, time of year, and the type, density, and distribution of its hosts.

Natural Control: Tick populations normally are regulated by climatological factors, availability of suitable vertebrate host populations, and, perhaps to a lesser extent, by their natural enemies (parasites and predators). Prolonged cold weather is detrimental to some species, whereas excessive heat, dryness, or rainfall may adversely affect others. Wild birds, domestic fowl, rodents, ants, and some species of parasitic wasps may play a part in the natural control of ticks. In addition, grooming by hosts and host-immune phenomena can reduce local tick abundance.

Figure 18-7. The California kangaroo rat (*Dipodomys californicus*), another reservoir host of *Borrelia burgdorferi* sensu lato spirochetes in California.

Chemical Control: Area-wide applications of acaricides to tick habitats may offer short-term control. Acaricidal applications are not recommended for large areas because of their expense, effects on nontarget organisms, and other environmental concerns. Acaricides are most effective when used to treat limited areas, such as lawns and the margins of trails. One drawback of applying chemicals is that they must come in direct contact with the tick. Thus, control failures often relate to the delivery system, not to the material itself. Another drawback is that some tick species develop resistance to acaricides following repeated exposures to a particular compound or class of chemical compounds.

Site-specific applications of acaricides can be quite effective against some ticks. The brown dog tick, *Rhipicephalus sanguineus*, for instance, can be controlled by treating kennels, dog houses, or other sleeping quarters. Similarly, the fowl tick, *Argas persicus*, can be controlled by applying acaricides to chicken houses and roosting areas. The relapsing fever tick, *O. hermsi*, can be eradicated from cabins or other dwellings in mountainous areas of western North America by a combination of rodent exclusion and tick-control methods.

Host applications of acaricides are most often used for controlling ticks associated with companion or domestic animals. Chemicals can be applied as dusts, sprays, aerosols, smears, dips, or systemics. Systemics are delivered either by injection or ingestion. Following their absorption into host tissues, ticks subsequently ingest the toxin as they feed. Repeated doses of systemics may be required to keep acaricides at an effective level.

Repellents can be applied to pets and humans to decrease the possibility of tick attachment. Tick and flea collars can provide effective protection for cats and dogs when used properly and replaced periodically. Repellents for human protection may be registered for application to clothing or skin, or both. The pyrethroid permethrin, when used as a clothing impregnant for personal protection against *I. pacificus*, was found to be 100% effective against larvae, nymphs, and adults.

Avoidance of Ticks: To avoid ticks, one must know when and where ticks occur. Different species inhabit different microhabitats. Knowledge of the life histories of ticks is important for developing preventive strategies. In general, individuals visiting tick-infested areas should stay in the center of trails and avoid sitting on the ground or on logs in brushy or woodland areas. Leaf litter in woodlands has been identified as the primary biotope of *I. pacificus* nymphs, which is the principal stage transmitting Lyme disease spirochetes to humans in northern California. Direct contact with low vegetation, especially along trails and where two vegetational types merge (e.g., brush and grassland), should be avoided. In particular, contact with vegetation bordering the uphill margins of hillside trails should be avoided because the adults of several human-biting hard ticks (i.e., *D. occidentalis, D. variabilis, I. pacificus*) tend to congregate there.

Personal Protection: Since avoiding ticks is not always possible, personal protection can be achieved by tucking pants into boots or socks, and shirts into pants. Wearing light-colored clothing has proven effective for detecting ticks prior to their attachment. Applying approved repellents to pants, socks, and shoes, and checking clothing and skin frequently when in tick-infested country provide further protection.

Environmental Modification: Habitat reduction can effectively decrease tick-host interaction. Vegetative management, such as removal of understory in forests, prescribed burning, or mowing grassland may provide short-term reductions in tick abundance. Removal of understory in forests has been shown to effectively reduce tick populations. Host control may be used to augment other tick-control measures in an integrated management program. Likewise, rodent-proofing cabins or houses prevents infestations of soft ticks (*Ornithodoros* spp.) that may transmit relapsing fever spirochetes. In extreme cases, removal or exclusion of deer have been shown to reduce infestations of deer ticks (*Ixodes scapularis*) in the northeastern United States.

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CHAPTER 19

FIELD SAFETY

Richard P. Meyer[1]

INTRODUCTION

The uniqueness of vector surveillance and control activities includes performing routine functions that place the vector control technician and related professionals in direct contact with vectors and potential exposure to vector-borne disease microorganisms. Moreover, routine surveillance activities are specifically intended to detect the presence of vectors and vector-borne disease organisms so that actions can be taken to protect the public from these possible hazards. This aspect of the technician's responsibilities involves considerable risk by placing them directly into the "hot zone" where exposure to a potentially fatal vector-associated disease can occur (e.g., hantavirus and plague). The risks associated with routine surveillance in most cases are acceptable with minimal likelihood of vector/pathogen exposure if the technician is: 1) properly informed of those risks, 2) provided with an established set of procedures (protocols) intended to minimized any contact, and 3) instructed on the correct use of personal protective and associated safety equipment. This chapter introduces the technician to federal and local requirements for job safety as it relates to surveillance activities and the common sense application of protocols and procedures that have been demonstrated to afford adequate protection against direct contact with vectors and exposure to vector-borne disease agents.

FEDERAL, STATE, AND LOCAL WORKER SAFETY REQUIREMENTS

The same federal and state statutes that apply to the safe handling and application of pesticides and herbicides (please refer to *Pesticide Application and Safety Training for Applicators of Public Health Pesticides* by Stimmann and Eldridge) also are applicable to surveillance activities involving potential contact with vectors and vector-borne diseases. Title 8 (General Industry Safety Orders) of the workers safety "Hazard Communication Program" further entitles every vector control employee to a safe work place and the "right-to-know" of existing hazards associated with their job requirements. The risks associated with vector surveillance activities certainly present hazards that are part of a vector control agency's service to the public with the dedication of resources and personnel to detecting the presence of both vectors and their disease agents that are known to affect humans. The fact that such hazards are associated with vector and vector-borne disease surveillance operations mandates sometimes extraordinary measures to assure the safety of vector control personnel assigned the task of "looking" for vectors and "isolating" infectious disease agents from animals sampled in the field.

ELEMENTS OF A SAFETY PROGRAM

A well-balanced safety program for vector control personnel under Title 8 requirements should include the following elements: 1) active supervision, 2) written safety instructions/protocols that detail actions for avoiding (e.g., proper handling) vector and vector-borne disease contact, 3) effective use of personal protective equipment (PPE), 4) safe methods for transporting vectors and etiological (e.g., infectious bloods) samples to the laboratory for processing, and 5) continuing education training to reaffirm safety procedures along with the common sense "do's" and "don'ts" of field and laboratory work. Vector control and local health agencies operating laboratory facilities that process potentially diseased (infected) vectors must do so in accordance within the guidelines established by the Centers for Disease

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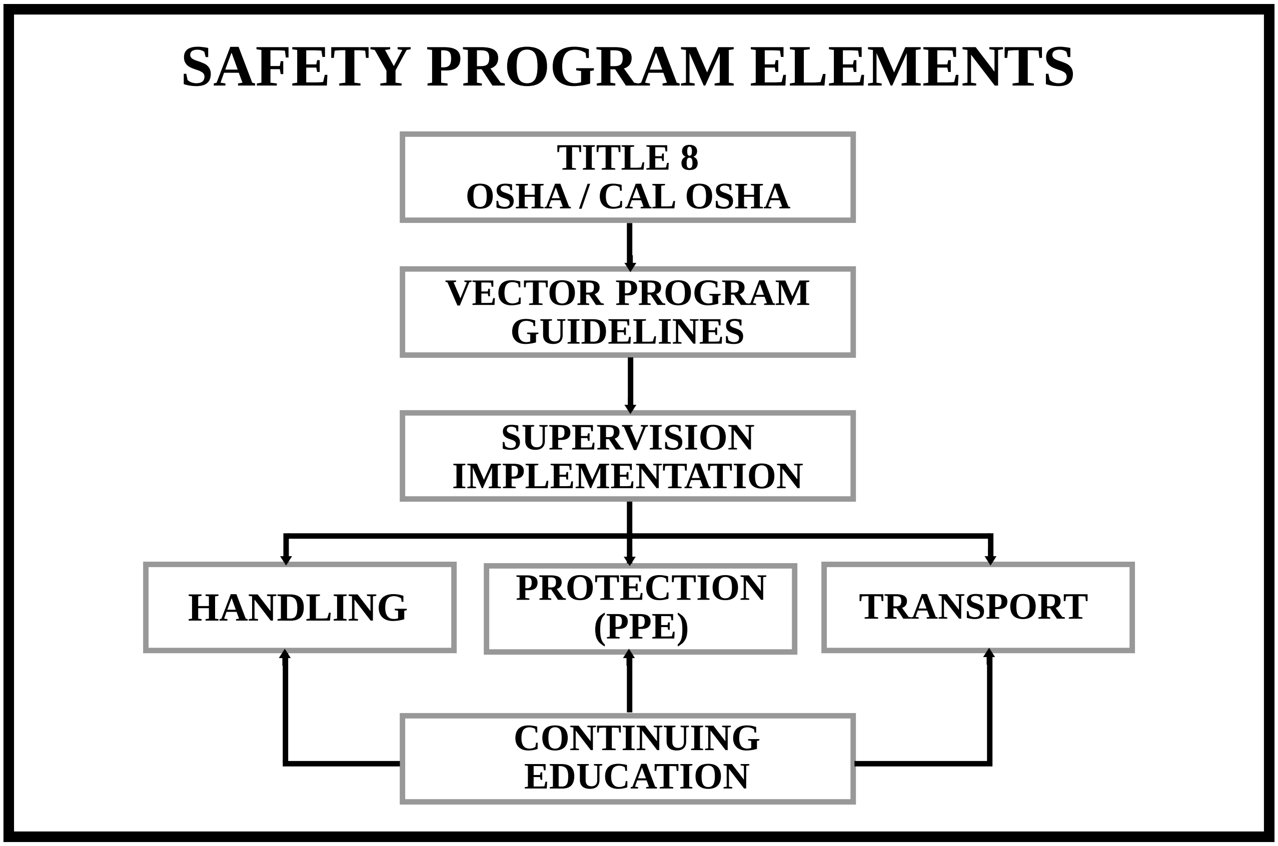

Figure 19-1. Elements of a safety program.

Control and Prevention (CDC). Laboratory programs include an additional tier of safety regulations that range from receiving samples, isolation (quarantine) requirements, to record keeping procedures. Laboratory facilities also are required to operate via a comprehensive written safety program that includes the protocols for each operation and/or diagnostic procedure.

Safety Programs

The safety guidelines provided by Title 8 as they currently apply to vector control operations are largely directed at handling and applying both pesticides and herbicides. Safety procedures implemented to preempt any accidental exposure to vectors or vector-borne diseases are not specifically identified either in Title 8 or in a vector control agency's Hazard Communication Program. They need to be included without exception as an employees' guarantee to a safe work place! A complete safety protocol includes the following components: 1) overview of the operation and attendant hazards, 2) types of possible exposure and their consequences, 3) proper use of required safety equipment, 4) proper use of surveillance and laboratory equipment, 5) emergency procedures in the event of an accidental exposure.

Supervision

Maintaining high standards and limiting the possibilities of an accidental exposure to a vector (e.g., bee or wasp sting) or vector-borne disease (e.g., hantavirus or plague) requires prudent supervision and constant reevaluation of ongoing procedures. The occurrence of an accidental exposure to a vector-borne disease as a result of not following procedures can have serious professional consequences affecting the credibility and management of a vector control agency. Therefore, it is incumbent upon management to continuously scrutinize ongoing surveillance activities and reinforce the insistence that all surveillance and laboratory safety procedures be followed to the letter without exception.

Personal Protective Equipment (PPE)

Clothing and special equipment worn by vector control staff that protects them from accidental exposure to vectors and vector-borne diseases is collectively referred to as personal protective equipment (PPE). The application of PPE is specifically designed to prevent accidental exposure via inhalation (respiratory exposure), ingestion (gastrointestinal exposure), and direct contact with either the skin (dermal exposure) or eyes (ocular exposure). PPE includes the proper use and application of protective clothing including gloves, goggles/safety glasses, headgear, and respirators that include HEPA-type and other air filtration devices.

Safe Handling and Transportation

Along with appropriate PPE, the safe handling and transportation of potentially diseased vectors and vector samples requires special techniques that also are designed to protect against accidental exposure to vectors and vector-borne disease agents. Obviously, when working with stinging Hymenoptera, sampling ticks and fleas, and collecting spiders and scorpions, there are correct handling procedures that minimize the possibility of either being bitten or stung. When transporting live vectors or whole blood samples back to the laboratory for further evaluation and testing, both "specimens" and "samples" should be transported in a manner that reasonably precludes any possibility of direct contact with the occupants of the transporting vehicle. This means that samples are to be marked with "Biohazard" placards, shielded, contained, and secured to assure that containment will be maintained, even in the event of a major vehicular accident. The best security against possible direct contact is having all samples carried in a compartment separate from the driver and passengers.

Ongoing Safety Training

The nature of vector surveillance and control activities includes constantly changing legal and technical requirements where new technologies and statutes

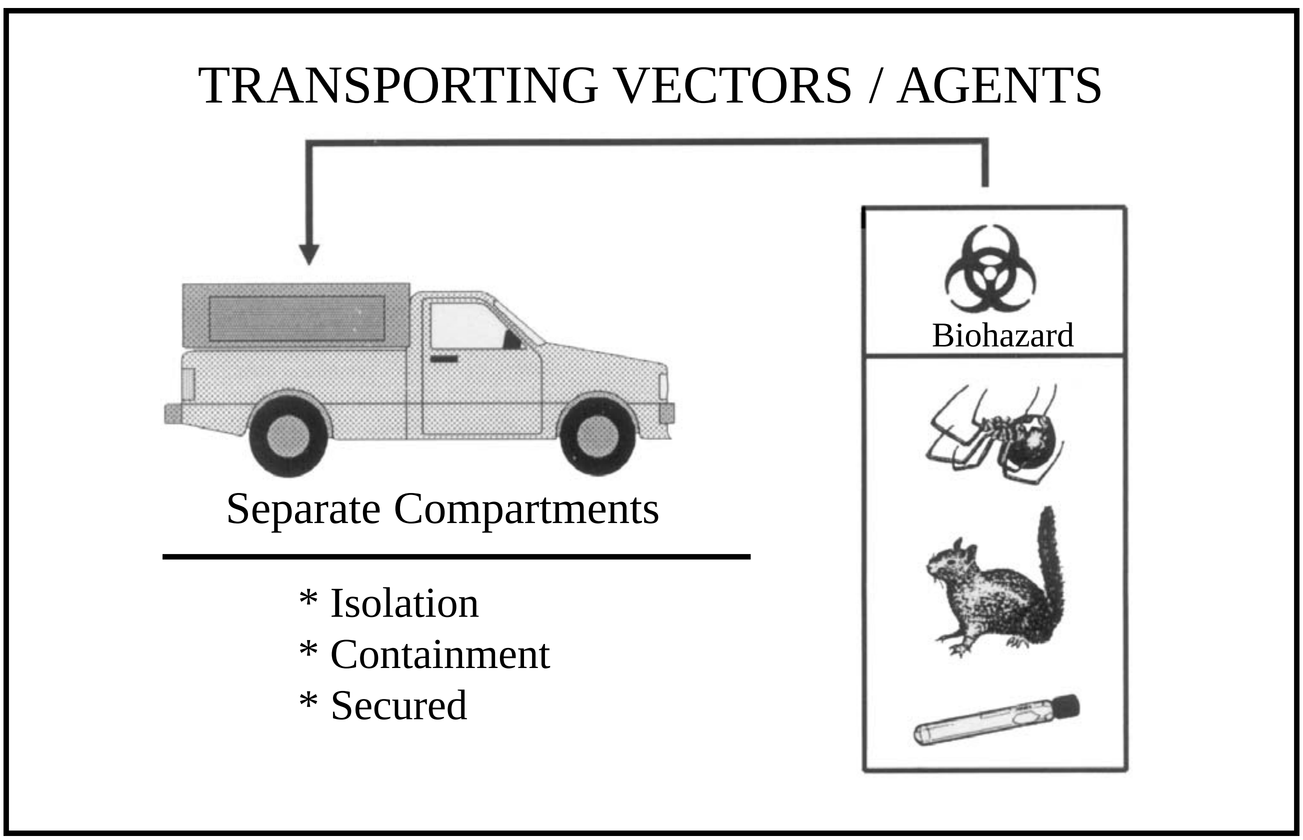

Figure 19-2. Safe handling and transportation of vectors and agents.

become inevitable. Knowing that changes occur as a natural consequence, vector control personnel need to be apprised of these changes on a routine basis. Therefore, regulatory agencies, such as the California Department of Health Service's Vector-Borne Disease Section (CDHS-VBDS) that certify technicians in vector control agencies, also require continuing education to keep certified personnel up-to-date on current revelations in vector biology, vector-borne diseases, vector management strategies, and pesticide laws and regulations. In conjunction with state mandated continuing education, federal law (e.g., Title 8) also requires that all employees involved with hazardous operations be subject to yearly scheduled training sessions to keep them 1) current with ongoing procedures and laws, and 2) apprised of the most recently introduced safety standards, protocols, and legal/ethical requirements.

Common Sense and Safety

There is no substitute for common sense when working with vectors in the field and in the laboratory. The vector control technician and any other staff member must realize that one careless act may have dire consequences as the result of casual oversight or just plain negligence. In either case, the outcome can result in an accidental infection, personal injury, infection of other staff, or injury to others not directly involved with handling vectors. Taking "shortcuts" or "modifying" a step in the protocol to save time often bypasses carefully prepared built-in precautions that are designed to maintain adequate safety should an accident occur. The best overall accident prevention behavior is to adhere to the currently established procedures and consult with a supervisor if there are any questions regarding existing safety protocols.

PROTECTIVE MEASURES

Personal Protective Equipment (PPE)

Clothing and Mosquito Netting

In most situations, protection from direct exposure to vectors simply requires wearing clothing that covers all exposed skin surfaces with the exception of the face and hands. Mosquito netting is usually worn over a wide brim hat to protect the face, neck, and ears from mosquito and gnat bites while the trousers are tucked into socks for protection against flea, chigger, and tick bites. Light colored clothing is preferred because the lighter colors make it easy to spot both ticks and fleas. The back of the hands can be protected by wearing lightweight fabric gloves. A good pair of snake guards and leather boots also may be required when conducting surveillance activities in rattlesnake infested areas.

Respirators

The recent discovery of rodent-borne hantaviruses in California introduces an exceptional requirement for limiting exposure to these agents when trapping and handling "field mice," such as the deer mouse *(Peromyscus maniculatus)*. Sin Nombre Virus (SNV) the infectious agent of Hantavirus Pulmonary Syndrome (HPS), are airborne pathogens that affect the lungs. Fatality rates among persons infected with SNV average 50%. Likewise, handling wild rodents potentially infected with plague also requires respiratory protection against the accidental infection. Therefore, when sampling rodents for ectoparasites and blood samples, it is prudent to wear a NIOSH (National Institute for Occupational Safety and Health) or MSHA (Mine Safety and Health Administration) approved HEPA-type high efficiency respirator that is designed to effectively filter out all pathogens down to the size of virus particles.

Insect Repellents

Situations may require the application of insect repellents to protect against mosquito, gnat, chigger, flea, and tick bites. Historically, the best protection afforded by repellents are products that contain the chemical DEET (N, N-diethyl-meta-toluamide) in varying concentrations. Although highly effective, DEET is suspected of being a carcinogen and should be used sparingly according to the product usage instructions on the label. Avoid direct applications to the face, especially around the eyes and lips. Instead, apply repellent to either the shirt collar and hat brim or wear a treated bandanna. Better yet, wear a mosquito net! Repellents are now available that do not contain DEET. However, these products must be applied more frequently because the chemicals producing the repellency loose their potency more quickly than products containing DEET. Among some of the newly developed products are lotions blended with sunscreens to provide dual protection from insect bites and UV radiation.

Bee Suits and Accessories

A number of vector control agencies in California now provide yellow jacket and Africanized honey bee control services to local residents. This unique aspect of vector control service requires special protection from stings and regular sensitivity testing of employees to assure their safety from a severe allergic response to sting venom. As part of an agency's safety program, a special supplement to the "Hazard Communication" should be available that specifically details procedures and PPE to minimize the chances of being stung and subsequently developing sensitivities to venom. Essential PPE includes the standard "bee suit," beekeepers gloves, boots, plus hat (worn under veil), and safety glasses. Water repellent (e.g., Tyvek®-type) disposable overalls may be worn over the fabric bee suit for additional sting protection, but only when the air temperature is at or below 80°F.

In the event of allergic complications resulting from either single or multiple stings (envenomation), each technician is required to carry a spring-loaded auto inject syringe (EpiPen®) supplied with a single 0.3 mg intramuscular dosage of epinephrine or similar recommended product. This chemical neutralizes the systemic effects produced by the massive release of histamines that accompany a severe and potentially fatal anaphylactic (allergic) reaction to the venom. Each time an employee or technician is accidentally stung, that individual should complete a sting exposure report that summarizes their reaction to the sting. This and subsequent sting reports track the sensitivity effect of the venom. If increased and more severe reactions to subsequent stings ensue, the enhanced allergic reaction may signal the development of hypersensitivity that may progress to life threatening in the event of a full blown anaphylactic reaction.

COLLECTION AND SAFE TRANSPORT OF ARTHROPODS

Collecting Equipment

The best way to reduce the possibilities of either being bitten, stung, or exposed to vectors while conducting surveys to obtain samples, is the use of proper collection equipment. Sampling spiders, scorpions, kissing bugs, bees, wasps, and other venomous arthropods involves inherent risks of a bite or sting if these vectors are mishandled. It is always wise to protect the hands and forearms from potential bites and stings. Overall protection is best provided by wearing gloves and using long forceps that afford a good grip for collecting large arthropods, including tarantulas, scorpions, and centipedes. Use of aerial nets to transfer specimens to either unbreakable plastic containers or killing jars treated with ethyl acetate can be used safely for sampling bees, wasps, kissing bugs, and corsair bugs. When using chemical killing jars, the container should be 1) clearly marked with a red and white poison warning label, and 2) indicate the chemical killing agent.

Transporting Vectors and Vector-borne Diseases

Conducting vector and vector-borne disease surveys invariably requires transporting samples back to a laboratory for processing and subsequent testing. Transporting samples involves a number of risks that can result in an accidental infection (exposure) if the proper procedures and containment requirements are compromised by negligence, a careless act, oversight, or unforeseen accident. Regardless of the situation, the result can be potentially dangerous when an accidental infection occurs, particularly when the exposure and subsequent infection leads to either hospitalization or an unfortunate fatality.

Containment

All pathogenic samples, including live vectors, should be transported in a manner that guarantees a low probability of escape in the event of a vehicular accident. Mosquitoes, biting gnats, and fleas need not be transported in indestructible containers, but in collection bags fitted to traps or other "screened" containers. The bags can be placed inside an ice chest or other suitable container that will sustain the impact of an accidental collision. The outside of the container should be clearly marked with "Biohazard" warning signs. For transporting spiders, scorpions, and various stinging Hymenoptera, it is highly advisable to transport these arthropods in tightly sealed containers (e.g., polycarbonate, polyethylene, etc.) that will not shatter when dropped on a hard surface. The use of zip lock bags is acceptable as long as the bags are placed inside a hardened shatterproof container.

SUMMARY

The unique role of vector control agencies and their intended mission to "seek out" vectors and vector-borne disease agents places technical staff at potential risk of exposure to vector bites, stings, and infectious disease agents. However, an informed vector control technician should be aware of these risks and act responsibly in accordance with carefully designed safety procedures. All it takes is a single irresponsible incident involving a careless act, negligent behavior, or unfore-seen accident to destroy the credibility of a vector control agency. Safety in vector control operations is designed for one implicit purpose, to protect the employee and the public from being harmed by vectors and pathogenic agents.

SUGGESTED READING

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A Guide to Cal/OSHA. California Occupational Safety and Health Program.

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