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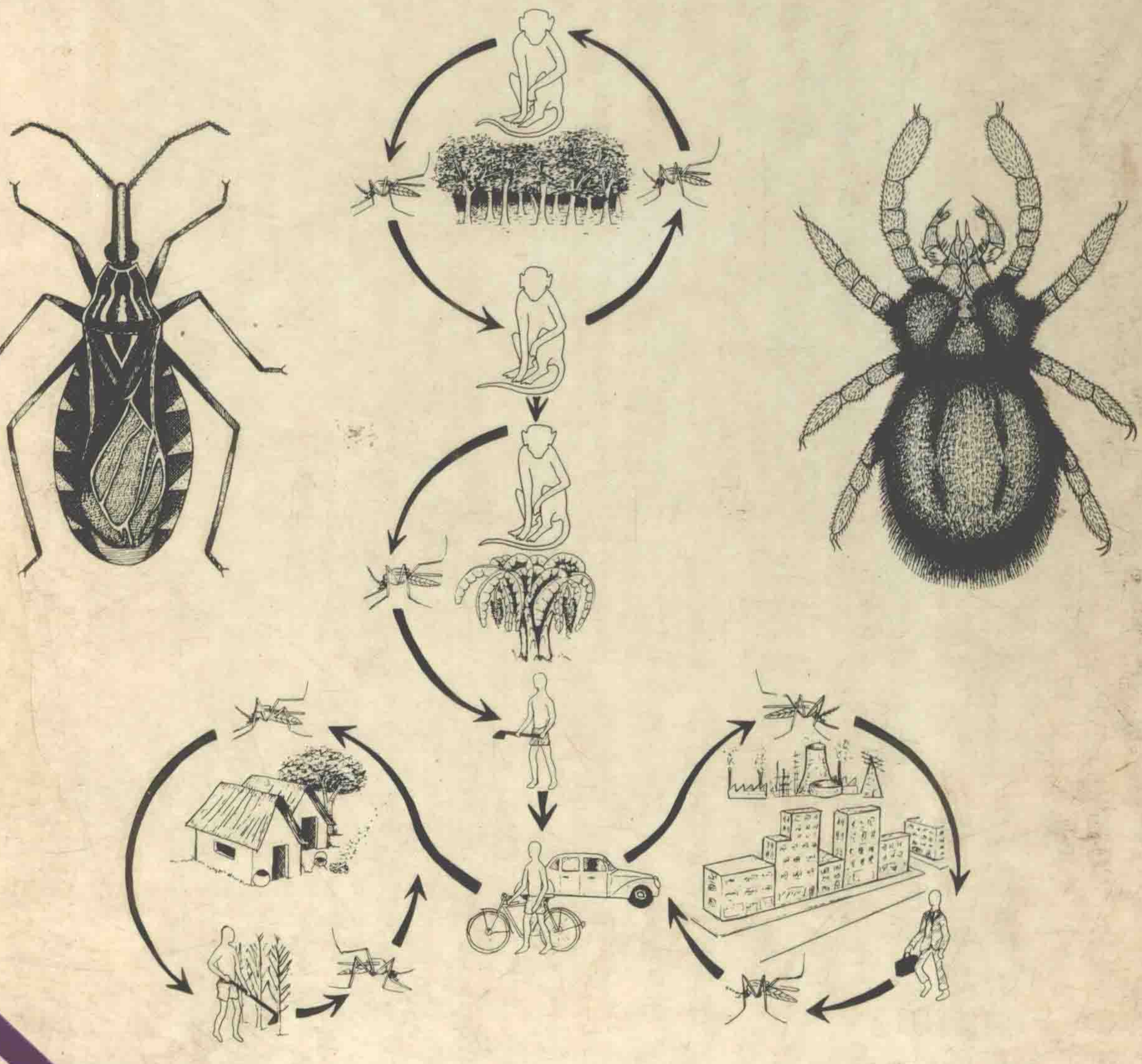
A Guide to Medical Entomology

M.W. Service



A GUIDE TO MEDICAL ENTOMOLOGY

M W Service

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A Guide to Medical Entomology

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Preface

This book is written for those whose work is concerned with medicine, hygiene, public health or parasitology but who have no specialised knowledge of medical entomology. Its aim is to provide basic information regarding the recognition of arthropod vectors of disease, their biology and life-cycles, their role in the transmission of diseases to man, and to present a guide to their control. It is hoped that the book will be used selectively to suit the varied needs and requirements of its readers. For example, it is unlikely that physicians being introduced to medical entomology will need to remember either the numbers or durations of the various stages in the life-cycles of the many different vectors. This type of information is nevertheless included in the book so that it can serve as a reference source. Paediatricians, nurses and community health workers will probably find the chapters on lice, bedbugs, scabies mites, houseflies and blowflies etc. more relevant to their needs than those describing the role of tsetse flies and blackflies in the transmission of sleeping sickness and river blindness. On the other hand students specialising in human parasitology or medical entomology will require to learn more from the book than others, and in addition will probably

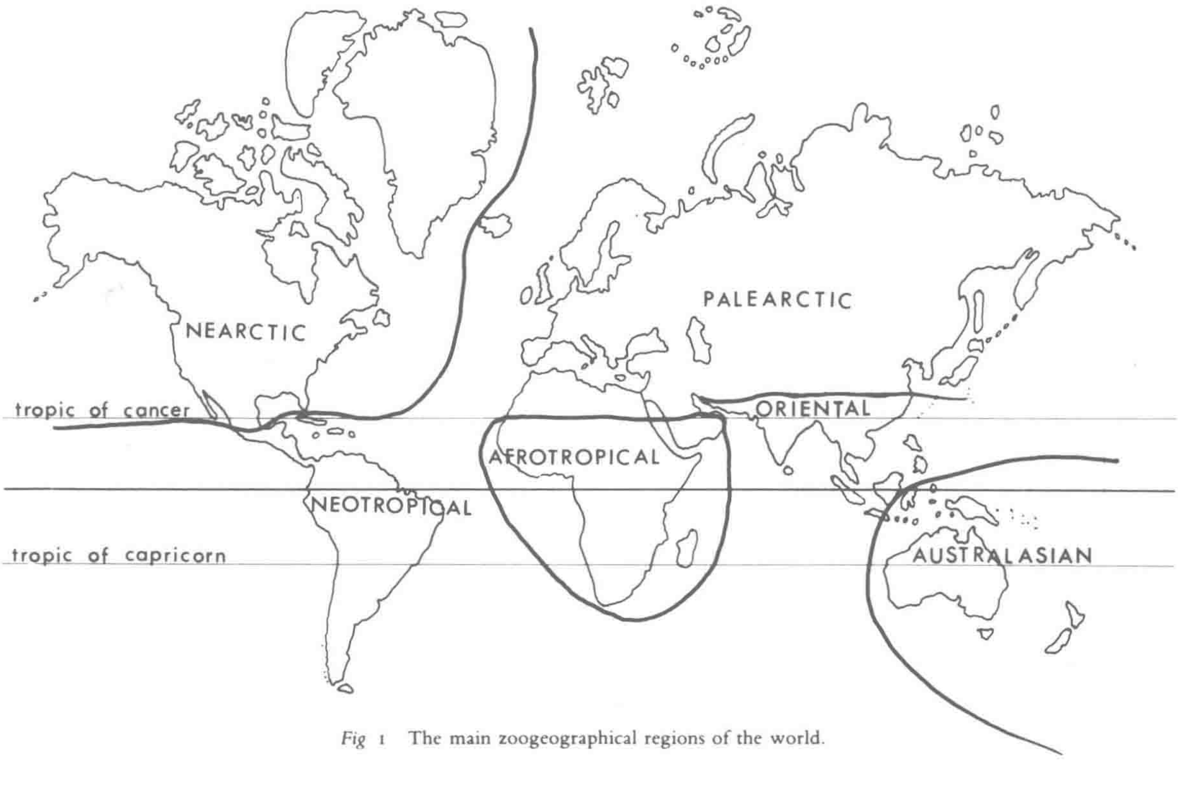

Fig 1 The main zoogeographical regions of the world.

need to refer to more specialised publications for greater detail on certain topics.

Attempts have been made to present clear and precise accounts of the vectors without unnecessary detail. For this reason little space has been given to detailed descriptions of arthropod mouthparts and only sufficient morphological details are given to identify the vectors.

Chapter 2 which outlines the classification and external and internal morphology of the arthropods is considerably shorter than found in most books on medical entomology for two reasons. Firstly, it is not considered essential that students interested in medical entomology need have detailed knowledge of this aspect of general entomology, and secondly it is realised that few students read such accounts!

The 'Recommended References' at the end of the book provide a starting point for those requiring more detailed information on various vectors or topics: where possible recent review articles and generalised papers and books have been cited.

When describing the distribution of vectors it is often convenient to refer to one or more of the six zoogeographical regions of the world, which are shown in figure 1. Basically the Palearctic region is the whole of the Old World north of about the Tropic of Cancer, the Nearctic region is America north of Mexico, the Neotropical region comprises Mexico and the Americas to the south, and Africa south of the Sahara is the Afrotropical region, previously called the Ethiopian region. The Oriental region is less easily defined, but comprises all tropical lands in the east, such as the Indian subcontinent and Malaysia, but excluding New Guinea, Australia, and New Zealand, which are collectively known as the Australasian region.

The drawings which are so essential in a book of this sort have been provided by Mr S. N. McDermott who has had considerable experience in illustrating medically important arthropods.

To Wednesday

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Liverpool
April 1979

M. W. Service

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1 Introduction to medical entomology

The study of insects is termed entomology. Medical entomology is a specialisation that involves the study of those insects that are of medical importance, for example mosquitoes, flies, lice and fleas. However, the term medical entomology is usually used in a broader sense to take into account the arachnids, a group of invertebrates that includes ticks and mites, that are not insects but nevertheless may be of considerable medical importance.

Historical

Some sort of association between certain insects such as fleas, flies and lice, and ill health of man has been recognised from antiquity, many of man's common ectoparasites are referred to in religious texts such as the Talmud, Koran and Bible. However, it was only during the nineteenth century that any definite proof emerged concerning the role of insects and other arthropods in the transmission of disease. For example, in 1868 Fedtschenko discovered that the guinea worm (*Dracunculus medinensis*) underwent its early development in a small copepod (*Cyclops*), it later being shown that man becomes infected by drinking water containing these infected crustacea. During the same year Melnikoff found cysts in the body of the dog-louse which Leuckart showed were those of a tapeworm (*Dipylidium caninum*). Its more common host, the flea, was not discovered until some twenty years later.

The most influential discovery of this period, however, was that made by the physician and parasitologist Patrick Manson. In 1877 while working in China he discovered that bancroftian filariasis (*Wuchereria bancrofti*) underwent development in mosquitoes, *Culex pipiens fatigans* (= *C. quinquefasciatus*). This provided the first real evidence that a pathogenic organism of man underwent obligatory development in an insect, and can therefore be rightly regarded as representing the 'birth of medical entomology'.

During the next 50 years or so a variety of insects, ticks and mites were incriminated in quick succession as vectors of diseases to man and animals, such as malaria, sleeping sickness, yellow fever, typhus, plague and relapsing fever. The rapid advances in understanding how these diseases were spread allowed the development of rational methods of control.

Why medical entomology?

Insects, and other arthropods such as ticks and mites (see chapter 2 for definition of these terms), can directly affect man's health and well-being by transmitting diseases, and so are said to be insects or arthropods of medical importance and are studied by medical entomologists.

Some insects, and other arthropods, do not transmit any disease but can nevertheless cause considerable nuisance and annoyance to man by their bites or stings, which may be poisonous or provoke severe irritations. Others, such as house-dust mites may induce allergies, while a few such as scabies mites actually live in the superficial layers of man's skin and are thus true parasites. Although many insects, ticks and mites cause considerable annoyance to man because of their bites, by far the most important medically are those that transmit diseases such as malaria, sleeping sickness, yellow fever and a multitude of other viruses, various types of filariasis including river blindness and many other diseases.

Great efforts have been made to control the major vector-borne diseases. In nearly all instances the most efficient control measures are those aimed at killing the vectors, whether these be insects, ticks or mites, for example spraying houses with residual insecticides to kill indoor resting *Anopheles*, vectors of malaria; dosing rivers with insecticides to kill the larval stages of blackflies, adults of which transmit river blindness; aerial insecticidal spraying of vegetation which provides resting places for adult tsetse flies which spread sleeping sickness. Because of this reliance on vector control to prevent the transmission of these diseases it is essential that the ecology and behaviour of the vectors is studied to ensure that the best control methods are selected and effectively applied. Moreover, knowledge of the biology, distribution and behaviour of vectors is necessary for a better understanding of the complexities of the epidemiology and spread of diseases, for example variations in adult longevity, feeding behaviour and predilection for human blood and seasonal abundance of *Anopheles* vectors will greatly affect the intensity of malaria transmission in an area.

Although medical entomology is often taught as a separate subject, it should not be divorced from the parasitological and clinical aspects of diseases. The medical entomologist should work alongside the physician and parasitologist identifying the vectors and providing information on their biology, ecology, seasonal incidence and breeding places. With such knowledge the medical entomologist is able to suggest the most suitable control procedures and the methods by which their impact on the vector population can be assessed.

Methods of disease transmission

An insect is said to be a vector when it transmits pathogens or parasites from one animal (including man) to another, thus *Anopheles* mosquitoes are vectors of malaria. Some insects are more or less accidental vectors and the methods of transferring the disease organisms are simple and relatively inefficient. Houseflies, for example, carry on their hairy legs, feet and bodies numerous pathogenic viruses, bacteria, protozoa and even helminth eggs which they pick up from excreta, pus or wounds etc. and they then deposit them on man's food. The pathogens undergo no obvious morphological changes or multiplication on the fly, which is acting solely as a *mechanical vector*. Moreover, these pathogens are not solely dependent on the fly for their transmission, as they are spread to man by many other methods such as people with contaminated hands handling food.

Another example of mechanical transmission is the spread of *Trypanosoma evansi* amongst horses by the contaminated mouthparts of horseflies (Tabanidae) and some other biting flies. During feeding the mouthparts of these insects become infected with trypanosomes which remain viable for short periods and can infect healthy animals if the insect feeds on them shortly afterwards. There is also mechanical transmission of myxomatosis to rabbits by fleas, mosquitoes and other blood-sucking insects.

As with the housefly the disease organisms undergo no developmental changes on or in the insect, which serves only as a mechanical vector, but in this case there is a difference because the spread of myxomatosis is dependent mainly on blood-sucking insects.

A more sophisticated relationship exists between insect vectors and pathogens when transmission to man, or animal, occurs only after the pathogens have undergone multiplication and/or some form of development within the insect. This is referred to as *cyclical transmission* of a disease. It follows that in cyclical transmission there is an 'incubation period' (usually lasting some 7—21 days) in the insect before the pathogens have undergone multiplication, morphological changes or migration and are in the correct state and place to be transferred to the new host. A simple example is provided by the rickettsial parasites causing louse-borne (epidemic) typhus which are swallowed by the body louse when it sucks blood from a typhus victim. The ingested rickettsiae multiply prolifically in the cells of the insect's stomach, after which they pass out with the faeces of the louse and man becomes infected when these are scratched into abrasions on the skin or inhaled. A rather more complicated development of a pathogen in an insect is evidenced by the trypanosomes responsible for South American trypanosomiasis (Chagas' disease). These are ingested by triatomine bugs when they feed on man or animals and the trypanosomes then both multiply and change into different developmental forms within the gut of the triatomine vector before the infective form of the parasite is produced and passed out in the faeces of the insect. Other trypanosomes, such as those causing sleeping sickness in man in Africa, not only undergo morphological changes and multiplication in the gut of the vector, in this instance the tsetse fly, but also have a complicated passage of migration within the insect's gut, so that the infective forms eventually occur in the salivary glands of the fly. When the tsetse fly feeds, saliva is pumped down the insect's mouthparts into the wound to prevent the blood from clotting and this results in the infective trypanosomes of sleeping sickness being injected into the host.

Disease transmission involving infected saliva of blood-sucking insects represents a more efficient procedure than most others. Malarial parasites have the most sophisticated methods of vector transmission. Not only do they multiply within the *Anopheles* mosquito but they also undergo a sexually reproductive cycle in the vector before the infective forms, the sporozoites, are formed and migrate to the salivary glands of the mosquito.

Some disease organisms such as filarial parasites, causing elephantiasis or river blindness in man, undergo morphological changes and migration in the insect vector but no multiplication. Many of the microfilariae ingested by vectors such as mosquitoes and blackflies are destroyed in the vector's gut so that only a few survive. Those that do survive penetrate the stomach wall and migrate to the thoracic muscles of the insect where they undergo morphological changes. They eventually develop into infective forms which pass down the mouthparts of the insect, and during refeeding are deposited on the surface of the skin which they penetrate. This type of transmission is clearly more complicated than mechanical transmission, but is not as complicated as in diseases such as malaria and African trypanosomiasis where there is both multiplication of the parasites and their injection into a new host with saliva.

In a few vectors, notably ticks and mites, pathogens such as viruses, spirochaetes and rickettsiae actually penetrate the ovaries of the vector. As a result the immature stages which hatch from the eggs are infected, and this infection usually persists to the adult stage. Consequently larval and nymphal stages (immature forms) and adults which have not previously fed on any host are able to transmit diseases. This unusual hereditary method of a vector acquiring an infection and transmitting it is termed transovarial transmission. When infection is acquired by one of the immature stages and passed to later immature stages or adults then it is referred to as transstadial transmission. Both transovarial and transstadial transmission may occur in the same vector.

Insect–man contact

The degree of association between hosts (man or animals) and arthropods (insects, mites, ticks) varies considerably. Biting flies such as mosquitoes settle on a host for only relatively short periods to take blood-meals, whereas triatomine bugs remain longer on a host while taking blood-meals, and some species of ticks may feed on a host for several days before dropping off. Bedbugs live in cracks and crevices in man's houses during the day but during the night leave their hiding places to feed on man. After engorging with blood they return to their daytime resting places. In contrast, fleas spend much longer periods on their hosts, but nevertheless are not permanently attached to them and frequently hop from one host to another.

Head, body and pubic lice are true ectoparasites of man and remain more or less permanently attached to his hairs or clothing. They are spread only by close contact. Even closer relationships exist with scabies mites which live in the surface layer of man's skin, and also with the maggots (larvae) of some specialised myiasis-producing flies which may penetrate deeply into man's tissues and sinuses.

Certain blood-sucking insects, such as some species of mosquitoes and tsetse flies, feed commonly or even predominantly on man and consequently have potential to be efficient disease vectors. Other species feed almost indiscriminately on man and animals or may even prefer animals to man. With these latter species, even if they are capable of transmitting various diseases to man, their importance is often reduced because there is less contact with man and therefore a reduced risk of transmission. However, this is not true with zoonotic infections where vectors become infected by feeding on animal reservoirs and then pass the pathogens to man, and where man to man feeding may be unimportant in maintaining transmission.

Specificity of vector–parasite relationships

The degree of susceptibility and specificity of vectors for pathogens and parasites varies greatly. With mechanical vectors there is often little specificity, for example any flies landing on excreta and man's food can in theory transmit a variety of enteric pathogens, similarly any insects feeding on rabbits with myxomatosis can spread the disease. In practice, however, some insects are more important than others as mechanical vectors because of their behaviour and habits. For example, the true housefly (*Musca domestica*) is a more efficient mechanical vector of cholera, typhoid and various dysenteries than other closely related flies because it is more likely to settle on both excreta and food than most other flies.

In South America the trypanosomes of Chagas' disease can undergo cyclical development in most species of triatomine bugs and consequently many species should be able to spread the disease to man by their contaminated faeces. However, only the few species of triatomines that live in close association with man and therefore frequently feed on him are important vectors. Similarly, all species of tsetse fly are capable of transmitting human sleeping sickness, but only some of the species that feed on man are efficient vectors.

With several other diseases there is greater specificity of the parasites for an insect vector, not so much because of their ecology or behaviour but because only in certain species can the parasites multiply and undergo development. For example, malaria is transmitted to man by mosquitoes belonging only to the genus *Anopheles*, because the parasites of human malaria are unable to survive or develop in other genera of mosquitoes. However, even within the genus *Anopheles* only in a few species do the malarial parasites succeed in completing their development and infecting the salivary glands. Thus in any area only a few species of *Anopheles* are malaria vectors. Similarly, in Africa yellow fever virus is transmitted from man to man almost entirely by the mosquito *Aedes aegypti*, despite the fact that many other *Aedes* species feed on man. In most other *Aedes* species there is poor survival and very little multiplication of the virus.

A further complication is that a vector species may not have uniform behaviour throughout its range, for example *Aedes simpsoni* commonly bites man in some areas of Africa and as such is involved in the rural cycle of yellow fever transmission, whereas in other areas it rarely feeds on man. Moreover, although a vector may feed on man throughout its distribution its vectorial capacity may differ, for example in some areas of Africa *Culex pipiens fatigans* is a good vector of the filarial parasite, *Wuchereria bancrofti*, while in other areas, notably West Africa, it appears to be a poor vector. These examples show that the epidemiology of many vector-borne diseases is more complex than might appear at first sight.

2 Introduction to the arthropods (insects, mites, ticks etc.)

Classification of arthropods

All insects and arachnids belong to a very large phylum of invertebrate animals termed the Arthropoda, a phylum which contains over 85 per cent of all known species of animal. All arthropods have the body composed of numerous segments, but many of these may be fused and consequently segmentation may not be clearly visible. The entire body is covered with a tough skin called the cuticle which in parts is chemically hardened to form a protective exoskeleton. The very simple heart is dorsal, whereas the ganglionated nerve cord is ventral but in the head region it connects to a dorsal large ganglion, often called the 'brain'. The body cavity (coelom), which is the space between the alimentary canal and body wall, is often called a haemocoele because it contains the arthropod's blood.

The class Insecta is the largest within the Arthropoda; other classes within this phylum include the Arachnida (spiders, scorpions, ticks, mites etc.), Crustacea (crabs, lobsters, shrimps, *Cyclops* etc.), Diplopoda (millipedes), Chilopoda (centipedes) and Pentastomida (includes tongue worms). All these classes contain animals of greater or lesser medical importance.

Insecta

The body is divided into three regions – head, thorax and abdomen, but in some insects there may be little external evidence of such differentiation. The head bears a pair of antennae and may also have one pair, occasionally two pairs, of palps which are modified components of the mouthparts. Three pairs of legs arise from the thorax, and usually there are one or two pairs of wings, but some insects such as fleas and lice lack wings. There are no walking legs on any abdominal segments. Respiration is by means of air entering small openings termed spiracles in the exoskeleton of the insect's body, these lead to tracheae within the body which in turn branch into small tracheoles which ramify the body and carry oxygen to the tissues. There may be a pair of spiracles on most body segments or they may be greatly reduced in number.

Arachnida

There are no antennae or wings but four pairs of legs. The body is either divided into two regions, one comprising a combination of the head and throax termed the cephalothorax (prosoma) and the other the abdomen (opisthosoma), or the body appears as a single unsegmented entity, such as in ticks. Respiration occurs by air entering one or more pairs of spiracles, often called stigmata in the arachnids, situated on the body.

Diplopoda

These are millipedes. There is a small head which has one pair of antennae and following this is a long cylindrical and segmented body which is not differentiated into a thorax and abdomen. Each apparent segment carries two pairs of legs and two pairs of spiracles.

Chilopoda

These are the centipedes and are superficially rather similar to the millipedes, except that the body is flattened dorsoventrally and each body segment has only one pair of legs and spiracles.

Crustacea

These have two pairs of antennae and at least five pairs of legs. The body may be either single and unsegmented, or segmented and divided into a combined head and thorax and a separate abdomen. Respiration is never by tracheae.

Table 2.1 Simplified classification of the arthropods, with mosquitoes (Culicidae) treated in more detail than other groups

Phylum: ARTHROPODA

Classes:
- INSECTA — Insects
  - *Subclasses*:
    - Apterygota — 4 orders: no medical importance
    - Pterygota — 24 orders: following of medical importance
      - *Orders (medically important ones only)*:
        - Dictyoptera — Cockroaches
        - Hemiptera — Bedbugs & triatomine bugs
        - Anoplura — Lice
        - Diptera — Flies
          - *Suborders*:
            - Nematocera
              - *Families*:
                - Culicidae — Mosquitoes
                  - *Subfamilies / Genera*:
                    - Toxorhynchitinae — *Toxorhynchites*
                    - Anophelinae — *Anopheles*, *Bironella*, *Chagasia*
                    - Culicinae — *Culex*, *Aedes*, *Mansonia*, *Haemagogas*, *Sabethes* and 25 other genera
                - Psychodidae — Includes sandflies
                - Simuliidae — Blackflies
                - Ceratopogonidae — Biting midges
            - Brachycera
              - Tabanidae — Horseflies
            - Cyclorrhapha
              - Muscidae — House-flies etc.
              - Glossinidae — Tsetse flies
              - Calliphoridae — Blowflies etc.
              - Oestridae — Warble flies
        - Siphonaptera — Fleas
- ARACHNIDA — Mites, ticks, spiders etc.
- DIPLOPODA — Millipedes
- CHILOPODA — Centipedes
- CRUSTACEA — Crabs, lobsters, *Cyclops* etc.
- PENTASTOMIDA — for example, tongue worms
- and OTHERS

Pentastomida

These include the tongue worms. They are elongated and segmented. The adults lack legs and other similar appendages, but the mouth is armed with chitinous hooks. Because of their segmented worm-like appearance they were previously classified as helminths not arthropods. They are parasitic in snakes and a variety of mammals including occasionally man.

Insecta

Classification

The class Insecta is divided into two subclasses, Apterygota and Pterygota. Within these subclasses are 28 orders (some of which may be divided into suborders) which are divided into numerous families (names ending in -idae, for example Culicidae – which are the mosquitoes), and sometimes into subfamilies (names ending in -inae, for example Culicinae, a group containing many genera of mosquitoes), and finally into genera and species, and sometimes subspecies.

Table 2.1 presents a simplified outline of this type of classification with, for example mosquitoes classified from the phylum Arthropoda down to genera.

External morphology of adults

Adult insects are divided into three regions – head, thorax and abdomen, divisions which in many insects such as flies are well differentiated, but in others such as fleas and some lice there is less distinction between these three regions. The thorax is subdivided into three segments the pro-, meso- and metathorax; in many insects, such as flies, these segments are more or less fused together (figure 2.1), but in others such as fleas they remain clearly demarcated (figure 15.1). The abdomen is divided into a varying number (two to eleven) of visible segments, though occasionally seg-